INVESTIGATION OF CONCEPTUAL AND LANGUAGE DIFFICULTIES AFFECTING THE UNDERSTANDING OF SEVERAL MECHANICS CONCEPTS AMONG SOME AFRICAN TEACHERS AND STUDENTS

BY

NTHOBANE CABLE MOJI

Submitted in fulfilment of the academic
requirement for the degree of
Doctor of Philosophy
in the
Department of Physics
University of Natal

Pietermaritzburg
1998

ACKNOWLEDGEMENTS

Professor Diane J Grayson was very vital in my past seven years through the arduous task of this study. She successfully induced the culture of hard work and loyalty for instruction and research in the field of Physics Education. She blossomed with commitment when she was encouraging me as the first secretary of SAARMSE during the hard times of its inception. She patiently guided me through this study as my supervisor, even from my hospital bedside when I was on the brink of dying from that car accident. Diane was great. It is my pleasure that I was her first student at this level.

The University of Natal Physics staff in Pietermaritzburg was very supportive with general facilities throughout this study, especially to my family during my ailing times of the devastating accident. Sandy and Karl were very patient in guiding me into computers and their software. I thank the people of that department.

I am very highly indebted to FRD because of the research funding they so lavishly gave for this study. It would not have been possible for me to complete this study if FRD had not so confidently encouraged and stood by me. My gratitude will never cease towards FRD.

Professor Olugbemiro Jegede in outlining the skills of research methods and report of results with the opinion of a thesis write-up in science education in his workshop at UCT in the third annual conference of SAARMSE, and to me personally.

During all this tedious and testing work, I sincerely and intimately missed Vindi with all her support and urging, she was the Precious, I missed Lebohang, the assimilator and the Tigerman, and of course, I missed Thabang, the accommodator and Sabusabu. I love them. May the Lord bless them and keep them.

Brian Jardine and his family, the Baptist family brethren in Eastwood and in general; my Real Vision Baptist congregation in Harrismith and the countless other Christian communities who prayerfully stood by me with supplications too deep for words throughout my tearful recovery, back to my studies; I say God bless them.

My fellow students in Maritzburg Varsity: Martin, Thabang, Tsokolo, Bongani, the SCF folks and many others, too many to count, all were fantastic throughout all my studies, Stakie sacrificed a great deal with accommodation for my comfort. I hid in Florina's house for many days when hard work needed no disturbance. Sam Tshehla and Lebohang Masiloane were God given also with accommodation. Teto and Madienyane were most helpful in the final printing.

Nthobane Cable Moji
November 1998

PREFACE

The research work described in this thesis was carried out in several Colleges of Education where African teachers are trained and Universities. Computations and analyses were done in the Department of Physics, University of Natal, Pietermaritzburg, from January 1992 to November 1998, under the supervision of Professor Diane J. Grayson.

The studies in this thesis represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use was made of the work of others it is duly acknowledged in the text.

ABSTRACT

The results of national examination in matric and universities showed that African students were performing very poorly in their studies and examinations in science and in physics in particular. The objective in this study was to investigate some of the difficulties both African teachers and students, that meant African learners, had in understanding physics, specifically mechanics.

The study consisted of investigation of two themes, namely, conceptual and language difficulties. Conceptual Difficulties were investigated by means of three questionnaire tasks. Task One investigated learners' understanding of the concepts of force, energy, power, momentum, speed and other related mechanics concepts in the context of boulders rolling down and up a mountain slope. Task Two investigated subjects' understanding of the force on a ball that was thrown up by the hand, went up to the highest position, and then turned and fell freely back to the ground. Task Three investigated learners' understanding of the positions where speeds, velocities, accelerations and forces were equal on a ball as it was going up and on its way down.

The Pilot group, among whom the wide pilot work of this study was done through some haphazard questionnaire, consisted of pre-service and in-service teachers selected from the North East Free State Highlands which was regarded as an appropriate location with a number of institutions with the necessary research subjects, since it was neither much urban nor much rural. Intensive study and analysis was done on this pilot work and it led to some real research study to be conducted within a more "focussed" group, namely, the Student group. This Student group which consisted of the first year physics students on the Pietermaritzburg Campus of the University of Natal, was selected for purposes of comparison. Two kinds of Reference groups were devised: for the Conceptual Difficulties investigation the Reference group consisted of physics lecturers and professors from several universities. Their unanimous responses together were regarded as a memorandum through which to correct the responses of the study subjects. For the Language Difficulties investigation the Reference group consisted of African physicists from several universities. There was no unanimous consensus on their mechanics concepts translations into their vernaculars.

Analysis of written results and interviews showed that African students experienced Conceptual Difficulties in mechanics. The Conceptual Difficulties were similar to those conducted in many other countries around the world by physics education researchers. The Language Difficulties were of two types. Firstly, a translation from a single mother tongue term into multiple English (the language of instruction) terms revealed a lack of clear concepts differentiation among the subjects. Secondly, there was no consensus, even amongst African physicists, as to which vernacular terms and English terms correspond. In addition, the interaction of the use of African vernaculars with an alternative conceptualisation seemed to have resulted to many of the research subjects believing in a quantity that is intrinsic to a person or object. This quantity had attributes of several different mechanics quantities, such as force, momentum, energy and power.

Two tasks were used in the second theme where Language Difficulties were investigated. Translations of conceptual terms that were supplied in Task One and Task Three of the first theme were given and examined. The phenomenon of reverse translation from mother tongue to English was identified as a source of Language Difficulties due to the availability of limited words for these conceptual terms in the vernaculars spoken in South Africa. However, the effect language on the subjects' understanding of mechanics was not simply the result of the lack of vocabulary, the study also showed that the research subjects conceptualised physics concepts differently from physicists, this was revealed by analysing their use of both English and their vernaculars.

The results of the investigations were then discussed and compared with those obtained by other research workers in similar studies around the world. Some approaches in teaching physics to African students in an endeavour to alleviate these unearthed difficulties were proposed and recommended in the conclusion. It was further encouraged that more investigations would show to appropriately and successfully instruct the African learners the physics concepts, since some institutions lately managed to produce African physicists and physics professors.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

OVERVIEW

1.1 INTRODUCTION

1.2 AFRICAN STUDENTS IN SOUTH AFRICA

1.3 NECESSITY OF RESEARCH

1.4 OUTLINE OF THE THESIS

OVERVIEW

1.1 INTRODUCTION

In this introductory chapter the investigator outlines how the study project was conceived, carried out and analysed. It is a study investigating the understanding of some mechanics concepts in physics by some Africans in South Africa, where "African" refers to the people indigenous to South Africa (i.e. beside the Hottentot and Bushmen, the Black people who occupied the southern tip of Africa before the colonization by the people of European and Asian descent).

Professor C. Graham, head of the Physics Department at the Pietermaritzburg campus of the University of Natal, in his inaugural lecture (Graham 1995), stated that there are very few people in South Africa who study physics compared to those who study other disciplines. He further added that one of the reasons might be that worldwide physics has the reputation of being a "hard discipline". For example, from 1990 to 1992 only 164 students graduated with a B Sc, 25 with an M Sc and 17 with a Ph D in physics from South African universities. The South African Institute of Physics indicates it has a total membership of physics graduates of only 529. Indeed, people qualified in physics are scarce. It is worse when it comes to the number of African students studying physics. When one looks at African student numbers in science, not only physics, compared with numbers of non-Africans, one notices a vast gap. A case in point is that in 1995, there were less than twenty Africans with Physics doctorate degrees produced from eighteen universities of the Republic of South Africa in all the years (SAIP Presentations; Investigator's personal survey). Such scarcity of African physicists contributes to the scarcity in African physics students because of the lack of role models.

In 1994 The ANC issued a policy framework document for Education and Training. The document stressed the poverty of the infrastructure for science and mathematics teaching at senior secondary school level among the African people in South Africa. Many teachers are underqualified and poorly prepared. As a result, they produce poorly prepared students in science and mathematics beyond standard seven, which is the fourth to last year of study before commencing the tertiary level of study, i.e. technikon or university. Only 12 percent of the African students in higher education pursued careers in physical, life, engineering and mathematical sciences (The ANC 1994a). The ANC (1994b) added that Black education suffered severe deficits in the area of science and that it is imperative that this area be developed (RDP 3.3.11.9).

Seretlo (1973) commented about the poor performance of Africans in science in general compared with other peoples of the country. Stating how very few Africans qualify in science, particularly in physics in South Africa, he showed how critics consequently have been tempted to believe that Africans are inherently incapable of receiving any meaningful scientific training. He discussed in depth the factors he believed have a negative effect on Africans' attitude to physics. These factors were: home background and environment, religious beliefs, iconoclastic image of science, language problems and facilities and opportunities which are scarce for African students.

The matriculation results in physical science and mathematics for Africans are very poor. This matriculation, sometimes called Standard Ten or Senior Certificate according to the South African schooling system, is the final secondary school level. Appendix 1 contains results of physical science at matriculation level for the two years, 1991 and 1992 for comparison, from the Qwa-Qwa region where the investigator conducted his study survey. He believed this region was the most representative of African education in South Africa because the region is neither very urban nor very rural (Section 3.4). The results showed that in physical science an average of 40% of the candidates score above 40% in the examinations. Few of these candidates manage to pass the selection scales universities use to select students into their science faculties. The investigator himself applied to be a science student in one university in South Africa, but in his matriculation certificate his marks were too low.

While African students fail examinations and selection scales, the investigator is convinced, just as Seretlo (1973) stated, that they did not lack the insight and ability to understand and perform well. It might be that they had difficulties which are not seriously attended to by their instructors or education authorities, and which might act as hurdles to their understanding of physics. It is for this reason that the investigator developed a desire to investigate the actual difficulties these African students have in understanding physics.

1.2 AFRICAN STUDENTS IN SOUTH AFRICA

It was necessary at this stage to briefly introduce the African students whose understanding of mechanics concepts concerned the investigator in this study. They are the offspring of the African people who are believed, socially and politically to have always been in the continent of Africa, dark brown in skin colour, labelled black, hence who inherited the label of "Africans" or "Blacks". Van Aswegen (1990), among other historians, refer to these people as Bantu-language speakers or cattle keepers of the southern part of the continent of Africa.

Thus "Africans" is used in this study to denote the black people indigenous to the geographical area covered by the Republic of South Africa. They are classified as the Sotho Population Group speaking Sesotho, Setswana and Sepedi to the west of the Drakensberg range of mountains (thick lining depicting a semi-circular tract in Appendix 2).[However, due to economic and labour migrations of these African populations, much mixing has occurred so that pure population at most places cannot be guaranteed anymore, Gauteng Province, for example has become a great mixture of all these population groups] and the Nguni Population Group, which occupies the East of the range, being the people speaking Xhosa, Zulu, Swazi, Ndebele and Tsonga. Venda people in the far North are also a part of this label of Africans in South Africa. This label is in much contention: some White, Coloured and Asian people born in South Africa classify themselves as Africans. The investigator, however, will use the label Africans for the above-mentioned groups, who were classified as Bantu people, excluding the Coloured and Asian (Indian) populations of South Africa. The Hottentot, Bushmen, Griqwa, !San and Khoi people who were originally not classified as Bantu people in South African population, are also not included in this study.

The communities of these Africans lived according to their own traditions and cultures before the white people arrived in this country. They had their own traditional beliefs, such as believing that lightning was created by a skilled "mutiman/muti lady" or kill someone who was an undesirable element in the community (Appendix 3) as Seretlo (1973) explains. However, when the white man came, Africans were colonized landwise; culturally, their traditions were declared barbaric; their life style was labelled evil and they were told they needed civilization from their colonisers. With the introduction of "civilization", cultures changed. Religious missionaries arrived in Africa, traditions were declared sinful and wicked. Some people believed and changed their culture to adopt the "civilized" cultures that were imposed on them by the newcomers, but some were obstinate about relinquishing their cultural heritage.

There is therefore some confusion among African people in South Africa about their socio-cultural identity. For example, the youth do not know whether to believe in the mutiman's lightning, or the scientist's lightning.

This confusion is passed from one generation of African people to another in South Africa (Seretlo 1973). The investigator grew up in such a community with this confusion. African students therefore come to the physics class with this confusion from home and are expected to learn and understand physics. while they have these above-mentioned difficulties in understanding while studying.

Another problem is that African students learn science in English (or Afrikaans), a language in which they may not be proficient, since their primary schooling is done in their vernacular. To make matters worse, African science teachers' command of English, especially scientific English, may not be very good.

If successful teaching, learning and understanding of mechanics concepts is to be achieved for African students in South Africa, the investigator believes that these students' difficulties in understanding mechanics concepts need to be investigated and then addressed.

1.3 NEED FOR RESEARCH

The investigator was a lecturer of physics at the Qwa-Qwa Campus of the University of the North for more than twelve years, lecturing all areas of physics to African undergraduates. While lecturing mechanics to the university freshers, he noted that the students were not doing well in physics. Given his own experience and marks. It therefore became interesting to investigate the reasons why Africans were doing poorly in physics.

1.4 OUTLINE OF THE THESIS

This work consists of a study of the difficulties in understanding several concepts in mechanics experienced by African teachers and students. The teachers, who constituted the Pilot group, were either the people who had been teaching physics to secondary students or those who were almost ready to begin that work. These teachers were considered to be among those responsible for preparing the matriculants whose examination results are shown in Appendix 1, through teaching physical science. These teachers therefore were considered pilot research subjects for the study of investigating the difficulties of Africans in understanding physics concepts in mechanics. A lengthy pilot task was distributed among the teachers with a wide variety of questions including conceptual, language and cultural questions. The main study group, labelled Student group was then selected, consisting of first year physics students at the University of Natal, all of whom received the same physics instruction. Task One used among these students was the restructured and properly reworded version of Task One distributed among the teachers for piloting.

Chapter Two contains a survey of literature. Some literature showed how the desired study should be done, how to select samples, collect data, analyse and report the final results. Further literature reported the work done by physics education researchers around the world in investigating similar difficulties from their student subjects. Reports were studied where these workers argued about how learning and understanding in physics could be achieved. They investigated conceptual and language difficulties around the world to determine if these issues help or hinder student understanding. Literature on the understanding of force was reviewed as well as literature on language and thought.

Chapter Three outlines the procedure followed in carrying out the research. The presentation of the problem, the hypothesis and the method of investigating are discussed in this chapter. The possible research sources of difficulties were reduced to the two that were investigated, namely conceptual and language difficulties. The decisions about who should be the study subjects and where they should be situated, are discussed in this chapter. The selection of samples which were the Reference group, the Teacher or the Pilot group and the Student group are introduced in this chapter. The construction of the questionnaires used in the two themes being investigated is also handled in this chapter, i.e. the construction of three tasks is explained in this chapter. Since mechanics is usually a starting section in physics curricula, it seemed proper to the investigator to choose it as an area for research in this study. Since most of the subjects in the pilot study conducted in the Free State Highlands region are the off-spring of Moshoeshoe and the Basotho people; the first task in this study was set in this context. The investigator thought it would be interesting to them to see how mechanics was applied by their ancestors to conquer the enemies. Task Two concerned the forces acting on a ball at various positions after it is thrown up in the air, while Task Three dealt with the speed, velocity and acceleration of the ball.

Chapter Four reports on the results from questionnaires, written responses, interviews and comments given during the investigation of conceptual difficulties of the study subjects, both the Teacher (called the Pilot) and Student groups. Unanimous responses from the Reference group were used as the "correct" answers against which all of the responses of the Pilot and Student groups were judged.

Chapter Five reports on the results of translations and comments on apparent language difficulties of Africans from both the Pilot and Student groups relating to conceptual terms which were answers in Task One (Appendix 4) and Task Three (Appendix 6). Responses in vernacular given by a Reference group of African physicists showed that there was no consensus among this group with respect to vernacular words for mechanics terms.

Chapter Six is a synthesis. Findings from this study are compared with those of other researchers, as outlined in Chapter Two. Similarities and differences are noted and discussed. Results of particular interest from this study are highlighted and general conclusions are drawn.

Chapter Seven is a concluding chapter with brief recommendations and advice. The final conclusion of the investigation is contained in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

2.2 RESEARCH METHODOLOGY

2.3 LEARNING IN SCIENCE

2.4 CONCEPTUAL DIFFICULTIES IN MECHANICS

2.5 LANGUAGE DIFFICULTIES

2.6 LITERATURE INFORMATION

2.7 SUMMARY

LITERATURE REVIEW

2.1 INTRODUCTION

Four aspects of literature are reviewed in this chapter. First, the literature on research study design and planning, i.e. all that must be done in this study to ultimately present an acceptable and reliable report, is outlined in this section; second, the literature on learning in science; then literature on conceptual difficulties and finally the literature on language difficulties.

Numerous difficulties of African students in learning were outlined in the Overview (1.1). McNaught (1994) worked among Zulu students and noted the following difficulties as compared to those who are non-African: the enormous differences in financial support both to teachers and students (as elaborated in Moji and Moji 1993), security and stability. For a multitude of African students in South African schools, many of their teachers have only attained Junior Certificate or Grade Ten, in academic qualifications, two years less than matriculation. Much work needs to be done to overcome these difficulties, and hence to improve teaching and learning, especially in sciences such as physics, among these African students.

Two themes were selected among several possible areas of difficulties in this research study, with the aim of limiting the number of variables (Section 3) that would be problematic to control if the study was much wider. These are (i) conceptual and (ii) language difficulties. The literature relevant to the work done on the themes by other research workers, and on learning itself, was reviewed in this chapter. The literature about the research methodology to be followed to achieve the desired results in this study is also reviewed in this chapter.

2.2 RESEARCH METHODOLOGY

Marks (1982) suggests steps that should be followed in carrying out a research study. He advises that the study should clearly articulate the following:

1. the overall objective of the study being done
2. the kind of data to be collected to provide the facts
3. the kind and the size of the subject samples to be selected from the population
4. how the data will be collected to render them suitable for analysis
5. utilizing appropriate techniques in data analysis and
6. the report of the study

Marks further recommends the use of the correct terminology. For instance, the object studied is called the experimental unit, an observation on the experimental unit is a response variable, a dependent variable or an outcome, while a universe is the practical population or experimental units. Marks finally warns against prejudice and bias by stressing the importance of validity which means the ability of the instrument to measure the phenomenon of interest accurately, reliability, which is the instrument's ability to constantly reproduce accurately, sensibility, the ability to confirm correctly the presence of response variable and specificity, meaning the ability to recognise and avoid faulty response variables. Among other things, reliability is very important and can be evaluated by consistency and stability of the instrument used. This reliability can be achieved by monitoring the response variable by comparing them with standardized reference responses while also controlling response variables with responses of a group in similar conditions to those of the experimental group, where this counterpart group could be referred to as the control group.

Leedy (1989) outlines the planning and design, which in many cases is called the research methodology of the study, as follows:

"It always starts with a question or a problem in the inquisitive mind of the prospective researcher: Why? What does it mean? or what is the cause of that? It is with such questions that such a research study begins. The problem thus needs to be articulated. The goal that must be arrived at with the research study must be explicitly and unambiguously stated. Specific plan of procedure to be followed must be clearly outlined. Here the plan and the design is outlined. How is it proposed that the goal must be reached? It is imperative that the principal area of investigation, the problem itself, be divided into manageable subproblems; by resolving these subproblems logically, the main problem is then resolved".

An appropriate hypothesis is proposed through which the study arranges tentative solutions to the problem; it is this hypothesis that directs the investigator to the facts. The study looks for the facts directed by the hypothesis and guided by the problem. The facts are then collected and organized. The study finally interprets the meaning of the facts leading to a resolution of the problem, thus confirming or rejecting the hypothesis and also providing the answer to the question that started the study process.

Fowler (1993) presents an even a more specific methodology in which five steps are outlined:

1 The purposes and goals for the study must clearly be articulated.
2 The sample frame and sample characteristics, the size, the age, the level of study and similar other characteristics, need to be presented at this level as designed.
3 Methods of data collection and questionnaire designs of good measures as reliable instruments of the study are then organized at this level; validation arranged through a set of X standard authority personalities, such as professors and lecturers in the field being investigated and ample piloting with counterpart subjects.
4 Interview as alternative data collection by trained interviewers going through similar data collection methods of validation, testing and controlling.
5 Data recording, analysis and reporting.

In short, the study needs to articulate the problem, pose the hypothesis and select the sample. Then data must be collected from which analysis should be done on a standard sample for validation, referred to as Reference group: a sample for pilot, referred to as a Pilot group and main test group, referred to as Test or Student group.

Sanders and Banda (1995) encourage educational researchers to ensure that their research is at all times both valid and reliable. It must be with confidence that data gathering tools and techniques are implemented, and honestly measure what they purport to measure so that the final research results provide an authentic interpretation of reality. They investigated the actual knowledge of a group of students of the English words they commonly use. They show that it is taken for granted that some words are known while their meanings are actually not understood. They ultimately show how numerous researchers are not concerned with how reliable the assumption might be that, say, the meaning of the words is known.

Sanders (1996) encourages science education researchers to interpret research data in such a way as to avoid obvious conclusions because all outcomes of research studies have important practical applications. Such outcomes need to be both reliable (or confirmable) and valid (or credible). In many instances the research validity, that is, its true value, gets obscured by inaccurate data interpretations and preconceived expectations.

2.3 LEARNING IN SCIENCE

The aim in this study was to investigate the difficulties or the hurdles that both African teachers and students have in understanding mechanics concepts in the field of physics. It was therefore deemed necessary to explain the meaning of "understanding" in the light of learning among African students in South Africa. While the Oxford dictionary states that "understanding" a subject is knowing the meaning of it, researchers and education psychologists define understanding in several different ways. White (1988) defines "understanding" as the ability to use knowledge to cope with situations. This "understanding" of the real world, not only for students, but for all individuals, is believed to result from learning science (Osborne and Freyberg 1985). According to the theory of constructivism "learning" is a process that involves an interaction between learners' current understanding of the world and new knowledge in the construction of their own new sense of how the world around them works (Ausubel 1968; Pine and West 1985; McDermott 1991; Moji and Grayson 1994; Redish 1994; Hynd et al. 1994).

This construction of sense, or rearranged acquired knowledge by learners provides a powerful basis for "understanding", and influences the learning (Hewson and Thorley 1991; Hewson and Hewson 1987; Sequeira and Leite 1991). Arons (1973) states that wider understanding in science would be achieved when students synthesize experience and thought into knowledge and understanding.

McCloskey (1983) reveals how students follow their intuitive beliefs in arguing in physics even when they are aware of Newton's laws. He illustrates this by giving a number of examples, such as the path followed by a stone that is dropped by a running man, where many people believe that the stone falls straight down. McCloskey warns that such beliefs are difficult to displace even after instruction.

Wittrock (1985) maintains that concepts that students already have before instruction often acquired naturally and informally, need to be understood. When students' information and ways of thinking are appropriate for learning science, instruction focuses on assimilating new ideas into old structures, while if students' knowledge and thought processes are inappropriate for learning science, the teaching leads to accommodative learning in which new conceptions are learned which "revise or surplant" the less adequate previously acquired frameworks. He further states that these generative processes of learning science, called assimilation and accommodation, lead to new developments in the measurement of student and teacher thought processes, cognitive structures, conceptualization, and what it means to learn science in a meaningful way. Assimilation and accommodation thus reduce the number and improve the nature of culturally induced alternative frameworks acquired about science. They also challenge the characteristics of teaching and instruction that can help students generate a scientific conceptualization starting from informal scientific viewpoints. When all these processes are occurring, background ancillary student knowledge is needed to make sense of scientific concepts and principles, including cross-cultural differences in student background knowledge about science. Wittrock further provides some data showing that culture influences the way learners understand concepts. An example of heat is given: the concept of caloric heat flow was found to be relatively common among learners in the United States, England, Canada and France, while in contrast, the scientifically more advanced conception of a kinetic view of heat flow, was found to be relatively common among Basotho learners in the south of Africa, who had never been taught about kinetic theory.

Bell and Freyberg (1985), explain further an important aspect of constructivism, namely that when a teacher teaches, his/her intended message is not automatically transferred to the minds of the pupils. Instead, each pupil constructs his/her own meaning from a variety of stimuli including words read or heard. The meanings constructed depend, amongst other things, on how pupils cope with the language the teacher uses in instruction. If the language used includes unfamiliar words, unexplained in the pupil's language, comprehension of what is taught will be obstructed.

From the theory of constructivism, it can be inferred that learners therefore come to the physics class with deep-seated conceptions constructed prior to instruction, preconceptions which are often non-scientific (Van Hise 1988). Hills (1989) also discusses how the untutored beliefs of the students are brought along to formal instruction. These untutored beliefs often differ markedly from accepted scientific theories and facts. He stresses the importance of teachers' understanding of these beliefs of students and suggests that this understanding helps teachers to be better prepared in undertaking science instruction. These non-scientific understandings or conceptions are named "alternative conceptions" or "common sense beliefs" (Halloun and Hestenes 1985; 1986). These alternative conceptions significantly affect what can be learned since they interact actively with the knowledge input, particularly if such an input is contrary to what is understood in these preconceptions (Osborne and Gilbert 1980; Gilbert and Osborne 1982; Watts 1983). Students' meaningful learning therefore requires teachers to have background knowledge of these preconstructed physics conceptions in order to help students interpret and accept the new physics knowledge (Grayson 1994a).

Students are therefore not empty buckets to be filled with knowledge without question, nor tabula rasa (blank slates) on which information can be written unconfronted or for the teacher to write on without regard of what already exists on it (Osborne 1985; McDermott 1991; Van Heuvelen 1991; Redish 1994; Moji and Grayson 1995). The preinstructional beliefs turn out to be very resistant to change, eradication or challenge if new information is introduced that tends to differ from the student's current beliefs. If instructors do not make conscious efforts to direct students into modifying the information to be incorporated correctly, the students will continue to reorganise and reconstruct the information incorrectly against the teacher's expectation (McDermott 1991). Only when teachers of these learners have made a proper diagnosis (Osborne and Freyberg 1985) of what the difficulties are can correct guidance be offered as to appropriate modifications needed to incorporate new information correctly (Zhaoyao 1993; Lightman and Sadler 1993; Redish 1994).

Halloun and Hestenes (1985), for instance, surveyed the common sense beliefs about motion held by high school students in Arizona, and obtained results that indicated that student beliefs frequently conflict with Newtonian theory, so interfering with physics instruction. Admitting that these common sense beliefs cannot be avoided, since they represent a codification of students' experience providing meaning, they should be regarded with genuine respect by the instructors as serious alternative hypotheses to be evaluated by scientific procedures, so providing students with sound reasons for modifying their beliefs beyond the mere authority of teacher and textbook.

Gunstone (1987) from Monash University in Australia carried out a survey on a large student population on the understanding of some mechanics concepts. He used among other tasks, the rocket problem, the pendulum problem and the pulley (Atwood) problem to ultimately assert that students come with some beliefs about mechanics topics before formal study of physics; such beliefs, he added, are difficult to replace even after intensive instruction.

Jacobs (1989) from Stellenbosch University, in South Africa conducted a study among first year university students where she compared perceived understanding of physics terminology with actual understanding of it. She chose 25 English words which are used in physics, words such as: pressure, proportional, acceleration and others. She found that the everyday use of these words distracts students from understanding the scientific meaning of the concepts. She concludes that careful attention by instructors is needed to avoid using everyday meanings of scientific words.

Touger (1991), however, indicates how concepts and the language that conveys them may be evident to a physicist or to a teacher but not to a student. He gives an example of a statement from a student, "energy is the power a thing has of doing work" showing the lack of differentiation by the student. Touger conducted an investigation among 673 university students to determine if the students did really comprehend the concept of force by asking which of the following four terms are synonymous with force: power, energy, push and action. 55% gave power as synonymous; 48% gave energy as synonymous; 52% gave push and 16% gave action. Touger further warns that however careful teachers are, they must continually be sensitive to the possibility that students may not be decoding from their teachers' words the concepts that the teachers believe to have encoded in them. He concludes that teachers and textbooks must be made aware of the need to avoid loose locutions such as "force acts" or "force pulls", but indicate that forces are exerted by one body on another body; that they be careful not to speak about "forces on X" but "forces exerted on X"; that they avoid "force due to gravity " but call it "gravitational force".

Common sense, naïve beliefs and Aristotelian approaches to the understanding of motion in physics have been studied in depth by many other researchers (McCloskey et al 1980; Minstrell 1982; 1994; Halloun and Hestenes 1985; 1987)

Von Glasersfeld (1991) discusses teaching and learning in terms of "radical constructivism". He distinguishes between training and teaching, training, which has to do with the trainee's performance, while teaching which has to do with the conceptual understanding which can only be inferred by the teacher based on how compatible the learner's understanding is compared to the teacher's understanding.

Grayson (1994a) investigated ideas about electricity among Zulu students. The purpose of this study was to identify the beliefs the students held prior to instruction, with the aim of determining a genuine meeting place between the old ideas and new information, in the belief that the greater the indigenous knowledge and the less the imported knowledge, the more likely it was that the latter would be assimilated and used. Rife superstitious beliefs were noted among these students, including beliefs about lightning. An African Ph.D student in physics, who had taught university physics for several years was found to hold the belief that lightning could be a creation of some traditional mutiman. Grayson further noted that some of the misconceptions could be due to language difficulties and would occur in cross-lingual instructional settings. She also recommended that if the traditional beliefs were not harmful, the instructor ought not to persuade students to relinquish them since they would fulfill two distinct purposes: (i) to help construct new ideas with the traditional beliefs as the background, and (ii) providing the ability to overcome the incorrect preconceptions. She then concluded by stressing the necessity for instructors to be aware that the ideas the students bring to the classroom affect their understanding and need to be taken into consideration in designing instruction.

McNaught (1994), working among Zulu students in Natal, South Africa, was motivated to carry out research into the problems among the students learning science at schools. She found that they brought to their science studies already well-formed frameworks of ideas about science topics which really impact on science projects. She recommends constructivism as an appropriate perspective on learning in this situation, where it occurs as an active construction of meaning as a result of reflection on the learner's experiences.

Monk (1994), who did some research work among students in London, England and Maseru, Lesotho, expresses his concern about the ever decreasing numbers of students who continue in physics studies in higher levels, such as at the universities. He complains that the physics teachers are very quick to focus on mathematics at the expense of the physics. This undue haste in the introduction of mathematics in physics, says Monk, results in the physics communities having to pay the price for their poor pedagogic practices, namely a decline in the numbers of students continuing in physics. Monk further warns that much education in physics continues to be based on a "jug and beaker" model of education process where teachers and professors are still pouring from the jugs of their minds on to blackboards for students to fill the beakers of their minds, copying mindlessly from the black boards and text books.

Meaningful learning occurs when newly acquired information is judged by the learner to be valid in the light of this preinstructional conceptions and interpretation (Champagne et al 1980; Hewson and Hewson 1983; Hewson 1985). These researchers see learning in terms of conceptual development or change and not the piecemeal accretion of new information. It takes place in a process named conceptual change consisting of two variants. When the new information is likely to be incorporated easily into the current and existing knowledge for the improvement of student's inadequacy in current knowledge, the process is labelled conceptual capture by Hewson (Hewson and Thorley 1991), or assimilation by Posner (Posner et al 1982). The second variant of conceptual change is labelled conceptual exchange by Hewson (Hewson 1981; Hewson and Thorley 1991; Redish 1983), and accommodation by Posner (Posner et al. 1982). This is a much more radical process where after the interaction of the new information with the current conceptions of the student, the student is compelled to reorganise or even replace his or her existing concepts since they appear inadequate for assessing and grasping the phenomenon being introduced (Hewson and Thorley 1991; Posner et al. 1982; Champagne et al. 1985; Strike and Posner 1985; Wittrock 1985; Pintrich et al. 1993; Hynd et al. 1994; Redish 1994).

Conceptual change, therefore, with both its variants, is a process that occurs against the background of the learner's current concepts on which she or he relies whenever a new phenomenon is encountered. For the new information to be assimilated or accommodated into the existing conceptual system, the new information must be:

1 intelligible: it must have meaning and make sense to the student
2 plausible : it has to appear from the outset to be able to be used for solving problems that could not be solved by the concept it replaces, while still being consistent with its predecessor.
3 fruitful : it must be extendable, suggest wider possibilities and open wider doors.
4 adequate : it must render its predecessor inadequate and cause the judging student to feel dissatisfied over it.

(Hewson and Thorley 1991; Posner et al. 1982; Pintrich et al. 1993; Redish 1994).

In summary, conceptual change is likely to occur if new information satisfies the four conditions listed above. Assimilation occurs when the student assesses the new information in the light of his or her existing knowledge and finds it acceptable; otherwise if the student finds the new information incompatible with his or her current knowledge, with great reluctance, the student may rearrange or reorganize his or her knowledge in order to accommodate the new information in the existing system.

Redish (1994) generalises these learning principles. From the constructivist perspective he suggests that individuals organize their experiences and observations of the world around them into patterns or mental models. During the process of being taught physics, the student will build mental models that will help him or her to develop qualitative reasoning about physics processes, structure further coherent and accessible models, and ultimately allow the student to apply physics as an expert in a creative manner. Redish further emphasises that it is possible for the student to have some knowledge without understanding, where formulae are applied blindly with no understanding. He also states that students, who are not tabula rasa, usually organize this haphazardly learned information into their own mental models. Redish then explains conceptual change in learning in the light of mental models while outlining the constructivist principles. The first principle states that individuals construct their models from their experiences. The second principle states that learning something which matches the existing mental model is assimilation that just extends the existing mental model, while accommodation is more involved in that it demands a change of the substantially established mental model, thus needing a more radical kind of conceptual change. Redish concludes his paper by stressing that lecturers need to know their students, and diagnose their actual difficulties in order to address these difficulties and lead them to meaningful learning.

In sumary, learning in science is a process whereby learners construct their own knowledge based on the interaction of the new information with their existing knowledge. For teaching to be effective, cognisance must be taken of student's pre-instructional beliefs, especially where these are in conflict with scientifically acceptable concepts.

The literature reviewed in this section relates to the first theme of the study, namely, conceptual difficulties that students have in learning and understanding mechanics. Extensive investigations on conceptual difficulties have been carried out in various fields of physics by many researchers. However, to limit the vastness of the large number of physics fields, this study will only consider the conceptual difficulties relevant to the African terms "Matla/Amandla" (force, power or strength) as viewed by other researchers who are not necessarily Africans in South Africa.

Researchers who worked on the conceptual understanding of mechanics among students (Watts and Zylbersztajn 1981; Clement 1982; Osborne, Bell and Gilbert 1983; McDermott 1984; Sequeira and Leite 1991; Grayson 1995), carried out investigations of students' understanding of forces on an object that was thrown up, continued upwards as its speed gradually decreased until it stopped, changed direction, and increased its speed downwards as it returned. Although many researchers around the world did some work using this task, only a selection of research reports are discussed here. In all the tasks, force orientations were investigated at three positions of the object, namely after it had left the hand on its way upwards, at a position where it turned and fell back, and at the same position as the first position but on its way downwards.

Watts and Zylbersztajn (1981) from Surrey in England conducted this investigation among secondary level students. The responses indicated that 85% of the students associated force with motion. Specifically, students believed that a body in motion implied the existence of a force applied in the same direction to cause the motion, and if the body is not moving, there is no force operating on the body. Their research subjects in general had the following beliefs:

1. When the object travels upwards, the force "pushing" it upwards must be an upward force; when it goes down, it is a downward force.
2. When it is stationary at the top position, there is no force acting.

Clement (1982) conducted a similar investigation at the University of Massachusetts, involving a coin thrown upward, going on its own and turning back along the same path. A typical answer from the subjects as the coin was upward bound was that the force from the hand must be pushing the coin upwards. The indication was that on the way up the force from the hand must be greater than the gravitational force, otherwise the coin would fall down from the outset. The subjects labelled the force "pushing" the coin upwards in numerous ways: upward force, force of the throw, applied force and other names. The observation here was that it was difficult for the subjects to think about an object moving in one direction, while the net force acting was in the opposite direction, thus supporting the hypothesis that the preconception "motion implies force" was used by these subjects.

McDermott (1984), at the University of Washington, discusses how students were shown the path of a coin tossed up in the air and returning almost along the same path down. When asked to draw the force diagram for the coin on its way up, the majority of the subjects indicated an upwards force and McDermott also interpreted this result to indicate students' use of a "motion implies force" preconception.

Osborne (1985), working on building on intuitive ideas, investigated ideas about force and motion. Pictorially (Appendix 8), he gave a multiple choice test to one hundred 16 and 17-year-old high school students. He used a tennis ball thrown up, and neglecting the air resistance, he investigated what forces the students recognised to be acting on the ball. 66% of the high school students indicated that there was a continuing upward force in the direction of motion responsible for the motion, even though they had been taught Newton's laws of force and motion.

Gilbert, Watts and Osborne (1985), from England and New Zealand, using, inter alia, the same pictorial multiple choice investigation as Osborne (1985) referred to above, elicited student views about force and motion using the interview-about- instances technique. 52 out of 75 introductory physics students indicated that they supported the idea of an upward force during the upward motion, no force on the temporarily stationary object, and downward force during the downward motion. These ideas also support the "motion implies force" preconception.

Sadanand and Kess (1990), from Connecticut high schools used a multiple choice questionnaire to investigate the understanding of the students about the force concept as a ball was thrown vertically upwards. The survey was done among 57 college-bound students. If students were to neglect the air resistance, then what forces did they think acted on the ball on its way upwards? The possible answers were:

- A Its weight, vertically downwards
- B A force that maintains motion, vertically upwards
- C The downward weight of the ball and the constant upward force
- D The downward weight of the ball and the decreasing upward force
- E An upward force acting alone for a while and then an additional force downwards

Of those who responded to the question, 88% chose one of the four answers that included the upward force. Of all students who chose an incorrect answer, 82% chose D. These results supported the inference that most students believe that a force is required to maintain motion, and that a changing velocity must indicate a changing force.

Finegold and Gorsky (1991) from Technion-Israel in Haifa report on the analytical technique which led to their identifying meaningful conceptual understanding of force by students. They were determining the consistency of students' application of force and categorised the students' thoughts according to their inconsistency in their responses. They recorded their findings on the beliefs of the students about periodic motions, translational motions and projectiles after which they concluded that their subjects, even after studying physics, still continued with misconceptions which implied either that they do not understand or have difficulty in applying the force ideas.

Sequeira and Leite (1991), from Braga in Portugal, worked on a coin toss problem similar to Clement, investigating student conceptions in which it was discovered that students believed in a relationship between force and velocity. The questionnaire was spread among 27 fourth-year university students. Many of these subjects (52%), were reported to have thought of the two forces on the upward bound coin as being gravity downwards and the force of the hand, which was a decreasing force. The general conclusion then was that their alternative conception was that "motion implied force".

Hestenes, Wells and Swackhamer (1992), from Arizona, designed the "force concept inventory" to assess student understanding of some basic mechanics concepts in introductory physics. They designed a multiple choice questionnaire that included the following question:

A boy throws a steel ball straight up. Disregarding any effect of air resistance, the forces acting on the ball until it returns to the ground are:

- A the ball weight vertically downward and the decreasing upward force
- B decreasing upward force till the highest point where the downward force begins to increase
- C constant gravity and gradually decreasing upward force
- D constant downward gravity force alone
- E none of the above.

The multiple choice answers in the test included the most probable preconceptions that students might have about forces on the steel ball. The students showed in the responses a large tendency to support the idea of the upward force on the steel ball mostly choosing answer B, where the force from the hand was decreasing. Clearly the students believed in an upward force prior to instruction in this study.

Thijs (1992) from the Free University of Amsterdam evaluated students' misconceptions of force among 190 students in a Dutch Secondary school. Students were in Form 3. Thijs noted that students generally associate continuing motion with a continuing force. In his investigation he administered a task in which a ball was thrown straight up in the air and asked questions about the forces on the ball on its way up, at its highest point when it turns around, and on its way down as it fell. The answers indicated that the students had the misconceptions that: in a rest position no forces are present; when an object moves at a constant velocity, a force acting on it is constant in the direction in the velocity; a force exerted on a body imparts impetus to it which will gradually wear off with time; increasing velocity requires increasing force in the direction of the velocity. He concluded by recommending that the introduction of the concept of momentum before other concepts in mechanics would be helpful to build up a conception of force which would be intelligible and fruitful to students.

Seepe(1993) investigated the force phenomenon among pre-service teachers in Bophuthatswana. A total of 120 teacher-trainees took part as the subjects in the study. He found that studies in reasoning about the relationship of force to motion (or lack thereof) in physics, revealed that students harbour erroneous ideas which can interfere with learning and are very resistant to change. Seepe further reports that students associated force with movement so that in collision, a moving object is considered to impart force to a stationary one; that force is always in the direction of the motion of the objects; that more force is a property that is greater in a stronger person than a weaker one and that more massive bodies exert greater forces than less massive ones. Having noticed that the majority of the research sample answered the questionnaire according to alternative frameworks, Seepe suggests the use of conceptual change strategies that would not only eliminate non-scientific beliefs like forces of motion, but would also develop students' abilities to apply general rules in particular instances.

McDermott et al (1994) of the University of Washington indicate how incorrect it is to use the criterion of success in problem solving in physics as an indication of mastery in physics since ample evidence has shown that students who easily solve physics problems may still have serious conceptual and reasoning difficulties. They recommend that if the difficulties of students are researched and known, such research can guide in the design of instruction that can address the needs the students have in the introductory physics. They used the Atwood machine task to investigate the students' understanding of some mechanics concepts: gravity, the tension in a string, massless pulleys and others. They identified students' problems particularly in the use of the Atwood machine and recommended how the relevant concepts should be addressed and be taught and how the curriculum should be put together.

Thijs and Van den Berg (1994) supported conclusions of several researchers who studied the world views and traditional beliefs of students. They found that most Africans did not distinguish the material world from the spiritual world. Hence, if science was to be embraced by an African student, that student needed to modify his or her own personal monistic world view, since it was discovered that for Africans, scientific views of the world and traditional views conflict with each other; hence incorrect conceptions about the external world create learning difficulties in science. For example, a rainbow is a good omen in one African community, while to the same community the refractive dispersion of sunlight in the mist is an evil omen. These showed inconsistent view points. In some communities Africans thought that when the stone was thrown upwards, the "Mudzimo" (ancestral spirit) on the ground was pulling the stone down. Interestingly, the researchers discovered that responses from their samples showed similar alternative conceptions of force to subjects from the Nederlands, Zimbabwe, Botswana, Lesotho and Swaziland. From several tests they concluded that language and other cultural factors strongly influence the process of science learning. Thijs and Van den Berg however, believed that although the cultural aspects influence concept formations, they did not affect the formation of physics preconceptions since the results of their coin problem in Holland and in Zimbabwe showed that about 87% of both groups indicated a force in the direction of motion, that is upwards! It was thus concluded that preconceptions of physics were the same in both cultures far apart and therefore across the world.

Cobern (1996) from Arizona State University suggests that science education and curriculum development in the non-western countries can benefit if the constructivist view of science learning can be considered and adopted. Previously the western curricula were just transferred to the developing communities leading to rote learning rather than understanding. Constructivism, however, assumes logical thinking as inherent to humans, regardless of culture, focussing rather on the learner's interpretation leading to understanding. Students in different cultures are expected to have different perspectives on science. He suggests that science education researchers should be persuaded to incorporate such points in curriculum development for curricula to be culturally sensitive. He further suggests that traditional cultures pose no threats to logic and thus they are no impediment to learning modern science. He adds that Constructivism involves constructing interpretations influenced by the prior knowledge leading to reasonable culture-specific science in a cross-cultural constructivism. That implies "one should not expect Nigerian students to understand science exactly the way students in western countries understand science". A Nigerian constructs a world view based on the Nigerian understanding of phenomena which need not necessarily be unscientific. He concludes that while he does not imply Japanese, American or African science to be unique, there are culturally influenced webs of meaning in which science is embedded in understanding from culture to culture. He states that constructivism will lead to understanding from culture.

Numerous other researchers around the world have investigated the force conceptualization held by students using the similar task of determining forces on the object that is tossed upwards and comes down, including Lythcott (1985), Hewson and Hewson (1987) and Grayson (1994b), to mention a few of them.

2.5 LANGUAGE DIFFICULTIES

The second theme which was investigated in the present study was difficulties in physics associated with language. Student difficulties related to the language of instruction have been widely investigated. Several researchers who worked on problems presented by second language being the instructional medium, discovered how the hurdles in understanding science were aggravated by the use of a second language. They also identified how problematic translations were, which implied not only the translation of words but also the transmission of the meaning of the idea being translated. Some works of these researchers are surveyed below with a summary of the findings and recommendations.

Vygotsky (1962, 1978) expressed concern about the interrelationship between thought and mind during the learning of, inter alia, scientific concepts. He warned that it was often wrongly taken for granted that interfunctional relationships never varied. For example, perception was thought to be identical with attention, memory taken to be perception, thought to be memory, and so on. He thus regarded the study of the interrelationship of language and thought to be imperative. He defined speech as verbal thought which he said had the primary function of communication, but was multifunctional. He emphasised that any cognitive developments were determined by language or linguistic tools of thought and the socio-cultural experience of the learner. He summarized that essentially the inner speech used by a learner depended on outside factors, while logic developed as a function of socialized speech. The learner's intellectual growth is contingent on his mastering the social means of thought that is carried in a language. Vygotsky concluded by stating that to understand another's speech, it would not be sufficient to understand his or her words only, the thought must be understood and the motivation must be known as well, since thought is born through words.

Seretlo (1973), in his inaugural lecture at the University of Fort Hare, outlines how socio-cultural issues retard the advance of Africans into scientific and technological fields. The following are the examples of African beliefs and practices he mentions that retard physics understanding: A father, who is always regarded as an authority in every aspect of knowledge, would teach that a rainbow is a path to heaven for the departed souls; sceptism and questioning would be socio-culturally considered disrespectful. A thunderbolt is taught to be an action of a sorcerer with fire in the clouds; a solar eclipse is thought to be an omen of catastrophe, while an Apollo flight to the moon is seen as taunting God with human curiosity as was the tower of Babel. These and many other teachings are brought by an African child to class and are difficult to displace. He also states that African languages can scarcely express concepts in physics. For example, in Zulu, he indicates weight and density as both isisindo; mass, gravity, speed and many other concepts have no terms. He concludes that it is difficult to coin words that will precisely describe concepts in physics.

Whorf (1973) expresses how language shapes the innermost thought. He indicates that all levels of thinking depend on the language which express them and that the language used is habitually structured by the environment of the user; hence language would shift with meaning from one environment to another. He states that what is usually called scientific is a "specialized" western language where some terms would be "specialized" to some categories. For example the term "space" would have a different meaning to a physicist and a mathematician than to an everyday English speaker. He further stresses that since culture, thought and what is in the mind depend on the environment, the same word may have different meanings. For example, the English "sentiments" is very different from the French "le sentiment"; a word for "tree" in Polish actually is the word for "wood" for the English speaker. Whorf describes how two related languages, using the example of Chichewa and Zulu, can use the same words but mean opposite ideas where "I ate" in Chichewa means I am not hungry while in Zulu it would mean I am hungry. Whorf warns that it should never be taken for granted that the same words would be understood in the same way by different people, nor the scientific terms by everybody.

Head and Sutton (1985) state that the resolution of a problem in understanding things usually involves adopting a particular way of talking about them. A person may struggle to make sense, say, of why a pan handle is not on fire but nevertheless is hot, by talking about heat flowing or conducted along the metal. As it happens, the particular words and their imagery can not be wholly satisfactory for the heat phenomenon, however they still serve many people, helping them to make an island of sense in a sea of otherwise disordered impressions."Words can hence form centers of crystallization of ideas". Once a concept is ultimately successfully integrated, or in Ausubel's terms "subsumed" into an individual's existing personal cognitive structure, it then becomes part of that person's repertoire of tools to make sense of the world.

Pines (1985) points out that language serves the dual purpose of thought and communication. The ability to acquire and use language leads to amplification of meaningful experience. Through language, proper transmission of cultural values from one generation to another is achieved. It is through language that individuals acquire information. Meanings of concepts can easily be constructed if the language in which they are carried is understood beyond any doubt. Pines concludes that much can be accomplished by virtue of language acquisition incorporating large conceptual content and cultural meaning.

Chomsky (1988) in his Managua lectures addressed the role of language in knowledge acquisition which he declared was complex and intricate while also wide ranging in scope. He explained that Newton understood physics as natural philosophy where philosophy meant scientific grammar. Scientists in the study of language and thought understood philosophical grammar to be a deductive science that was immutable, that is, science and language study should be a single endeavour. A language speaker developed a system of knowledge represented in the mind and ultimately in the brain. In his demonstration of language having the ability to carry knowledge across, he proposed two concepts of ability: ability retained and ability lost;

from these concepts the conclusion could be made that knowledge was ability. Chomsky continued to show how almost impossible it was for a Spanish verbal expression to be translated or interpreted into English. He felt that it was only a person mastering the rules and principles of both languages who could successfully monitor the transference of knowledge from one language to the other. He further stressed that language acquisition in a learner was the degree of precision with which the learner imitated the adult. He concluded that though words may not precisely match across languages, the conceptual framework in which they find their place was a common human problem. However, such a framework could be modified by experience and cultural contexts.

Rollnick (1988) carried out a research study among high school students in Swaziland, investigating mother tongue instruction, intellectual environment and conceptual change strategies in the learning of science. It was discovered that among students not taught in their mother tongue, language difficulties resulted due to poverty in language clarification. For example, with the concept term force, one word was found to be used for several words in the foreign language (English). It was further found that use of mixed languages of English and SiSwati was preferable among these students to a pure version of either one, since they could clearly understand their mother tongue, while English must come in because it was thought to be rich in conceptual terms which the mother tongue lacks.

Rutherford and Nkopodi (1990) in South Africa investigated the phenomenon of translating science conceptions and investigated how accurately the English definitions could be translated into Sepedi (North Sotho) for second language speakers. They noted, among other discrepancies, that logical connectives did not exist and were not supported from the view of African languages in transmitting thoughts and meanings in western science. They also discovered that bilingual students usually perform better when instructed bilingually, particularly in science.

Marshall and Gilmour (1990) worked among grade 10 to grade 12 in Papua New Guinea. They understood the aim of teaching physics as being to introduce students to new ways of looking at the world. This depended on how students comprehended essential words which expressed physics concepts. They noted that students appeared to understand words used, but their understanding was different from the understanding of the teacher. They suggest, in their report, that teachers need to be aware that effective communication and comprehension will not always be as good as expected, hence teachers should take special care when using words that can be understood differently until students have grasped correct conceptions.

Von Glasersfeld (1991) emphasizes that each individual needs to have proper meaning of words if clear transference of concepts is to be achieved between two people or from a teacher to a student. He argues that for the teachers to "promote successful learning", teachers should know well what the student's ideas already are that will help the students to "construct the desired understanding".

McKinley, Mcpherson Waiti and Bell (1992) conducted a study on the effect of language and culture in science education among the Maori communities in New Zealand. They found out that translation can never be just a simple substitution of a term but also the different concepts need to be communicated to a varying degree. The more different the two cultures are between which translation must occur, the wider the gap between thoughts conveyed by the words to translate, hence the more difficult the final translation. It was found that this interdependence of thought and language was very strong in science and mathematics education. It was concluded that since language interacts with thinking, there can be no perfect meaningful translation from one language to another since language influences thinking.

Moravcsik (1992) argues about the necessity of knowing the language and culture of the instructional language. He states two explicit aspects relating language and mind. Firstly the language is trusted in expressing what is contained in the mind such as concepts of constitutions and triangularity. Language can also be understood by the mind more deeply than only what seems to be an "inkmark" on the surface. Deeper meanings might be attached to the parts of language, and understanding some words amounts to matching concepts with the meanings which are assigned to these words. Moravcsik concludes by stating that to know the meaning of the word is to be able to explain the virtues of what counts for the word, while to understand the same word is to have a representation of the articulation of the virtue explained.

Inglis (1993) taught English as a second language while using it as an instructional language to Science Foundation Programme students at the University of Natal. She discovered that it is through the articulation of ideas, inferences and observations that learners come to understand scientific concepts and thus construct their own knowledge. When tasks were to be done in English by these students, the lack of scientific comprehension resulted in poor ability to express themselves which prevented adequate achievements on the task. From the observations, therefore, Inglis concluded that the inter-relationship between concept development and second language mastery must be seriously developed in the design of the study program, necessitating the collaboration between the language teacher and the subject specific teacher.

Rutherford (1993) from the University of Witwatersrand investigated how the problems of scientific language were exacerbated by learning in a second language, specifically in South Africa. It was stated that English was used as the medium of instruction for 90% of students while it was the first language of only 5% of the whole population (2 million out of 40 million). It was revealed from this work that spoken language had hidden expectations and unspoken assumptions that people being addressed have the same background and underlying beliefs as the speaker. It would therefore be unsafe to assume that the learner has the same meaning in mind as the teacher. The examples related to the physics concepts of field and energy, which are very tricky concepts to define in a scientific context. Having studied these language problems extensively in South Africa, Rutherford proposed strategies for teaching in English as a second language, leading students to be more articulate in presentations and more competent and more confident in using their text books.

Nkopodi and Rutherford (1993) identified how scientific language, being impersonal and having specified vocabulary, was problematic to novice science learners and teachers. These results were deduced from records and analyses collected from different science teachers. Clear evidence was found that such language often led to misconceptions that could be accounted for by misinterpretation of some words and phrases. An example was heard when a teacher asked a student: "What is a unit of power?".

" A what?" asked the student with a poor pronunciation.

"Good, you are clever!" said the teacher thinking that the student said a "watt"!

McNaught (1994) in Pietermaritzburg investigated some of these language difficulties particularly among Zulu students who were only marginally familiar with English. She found it reasonable to suppose that for those learning in English, the greater the disparity between the usage of Zulu and the usage of English, the more the difficulties that were encountered by the learners. She further states that many African languages do not have the linguistic capacity for western scientific explanation although they have richness about some ecological concepts, social relationships and spiritual values. Thus she feels that difficulties in explaining science concepts such as force, energy and others, do not indicate that the language is deficient, but that there had not been a need for certain understanding or using certain concepts in former times. Straight translation of curriculum concepts from one language to another is rarely satisfactory. She further states that language is a public system of symbols constantly being made to respond to exigencies or needs of the changing world. She thus expects the necessary language or word coining to be able to accommodate new concepts. The meanings attached to words are not only linguistic, but also have emotional and cultural connotations, such that translations always need to be embedded in current cultural ecology.

Nangu (1994) investigated the effect of the medium of instruction on perfomance in physics tests. It was found that better understanding was shown on translated (into mother tongue) versions than on those in pure English. Although she stressed she was not advocating the translation of study material into vernacular, it appeared essential from her project that teachers needed to be aware that in vernacular students will have more understanding in science teaching. Nangu concludes that the mother tongue would assist in voicing alternative conceptions, clarifying them, eliminating misconceptions and articulating ideas formed from learning new ideas. Mother tongue thus tends to be useful for developing vital understanding. However, it should not be overused, but rather should decrease with the increase in experience of the student in the second language.

Thijs and Van den Berg (1994) observed cultural factors in the origin and remediation of alternative conceptions in physics from several countries of the world and reported how language had been found to interfere with the learning of science concepts when science was taught in English to students with, say African or Asian mother tongues. It was found that the use of logical connectives in science was very difficult, showing that while language was a factor in learning and teaching, it was also related to the formation of preconceptions, which in turn are difficult to remove once they are in the student's mind. Views were highlighted that indicated how language and thought lie between two extremes, where on the one hand language was seen as necessary to shape thought, leading to conceptualization, while on the other thought was necessary for the existence of universal roots in human cognition and capacity for language. Thijs and Van den Berg favoured the notion of the relationship between language and thought as being important in conceptual development in science, where concepts and notions were language dependent, so that speakers of different languages tended to have different understanding of the same concepts.

Dooms (1995) describes problems in learning and teaching science in English to students who use English as their second language. He investigated the descriptions and explanations of key concepts in science and how these contributed to the construction of meaning and understanding. He cites the work of Vygotsky (1962) and others to show that "culture provides the social context in which the individual and social construction of knowledge occurs, meaning language and world interaction facilitate concept development". He states that language structure influences the understanding of science concepts and it is the forms of language structures which determine knowledge and understanding. He further states that students' constructions contain numerous discrepancies, misconceptions and wrong views in their definitive systems so that their prior knowledge brought to the classroom is a precognition. He warns that teachers need to be aware of what students already know and that they have made sense of their prior interaction with the world so that teachers can thus be in a better position to facilitate further learning. Dooms used clinical interviews to investigate the understanding of some concepts presented in English compared with the same concepts presented in different mother tongues in terms of whether they made sense and both meant the same ideas.

Lynch (1996) investigated how language and culture influenced the learning and understanding of science by students in Tasmania and the Philippines who used English as their second language. His study contributes to the debate on which language of instruction to use in developing countries. His work involved a comparison of key concept terms in two languages of the Tasmans and the Philippinos against the terms in English. He compared sentence constructions and translations to determine if sense and understanding were indeed carried across into another language.

Sanders and Sebego (1996) indicate that learners' beliefs affect the way they learn new scientific concepts. In most cases the ideas they hold, being scientifically unacceptable, impede meaningful learning, hence it is suggested that it is important that teachers identify existing ideas held by their students before they start teaching new work. The authors noted a serious problem where Setswana terms used by their study subjects had a number of English equivalents. They warn that words used in teaching any of the sciences needed clear definitions since language was to be used to communicate precise meaning.

Grayson (1996) warns that learning and teaching physics is difficult even for students receiving instruction in English as their mother tongue who also come from societies which are technologically sophisticated, but the learning is even more difficult for students studying in a second language and who have a limited scientific vocabulary. For such students research has to take cognisance of language and further socio-cultural issues in trying to develop effective physics instruction. She suggests that as part of the solution to the problem of physics learning; to such students, it is much better to use a laboratory based or a guided discovery method. She emphasizes that such laboratory work enhances students' confidence, encourages student - instructor discussion in pure English and inter-student conversations in mixed mother tongue and English leading to the articulation and elimination of alternative conceptions.

While language difficulties were investigated in this study, it was, however not possible to isolate these difficulties from some socio-cultural issues that are intertwined with language. Some literature referring to such intertwining is added below.

Seretlo (1973) and Jegede and Okebukola (1991) outline the relationship between African traditional cosmology and student's acquisition of a science process skill. It was important to encourage students to develop skills in scientific observation through which they could independently recognize phenomena occurring in nature with watchful and critical attention. Jegede and Okebukola (1991) acknowledge that the African traditional world view and beliefs are vital variables influencing researchers in an African setting, particularly the religious and philosophical beliefs. In Nigeria they demonstrate that such traditional world views and beliefs are part of the cause of the underachievement of students in science and technology. It was further shown how superstitious beliefs and taboos hinder the learning of science. Noting the hindrance, they proposed that the science curriculum for Africans, including physics, needed to be modelled through the African thought system which the learner usually brought to the classroom and used as a conceptual framework for constructing personal ideas about phenomena. Such modelling would be supported by two major educational paradigms: (i) constructivism, in which a learner constructs his or her knowledge on the basis of new experience interpreted in terms of a previously constructed conceptual framework, and (ii) the world view learners in traditional societies take to the classroom. They further recommend that curriculum and instruction for science in non-western societies must begin with and reflect the world view these students already hold. It is only through implementing this recommendation that a firm foundation for the acquisition and use of basic scientific processes will be laid.

2.6 LITERATURE INFORMATION

The literature surveyed in this chapter was about learning, understanding, the research methodology and Conceptual and Language Difficulties.

Indeed there were numerous other references which agreed with these references mentioned above; that is, those referring to learning, conceptual difficulties and language difficulties of learners; in cases such as those of the Maori people in New Zealand, the Phillipino people in the Phillipines, and others mentioned above who were taught science in second language. There were many such cases, only a sample of which have been included in this chapter.

Conceptual Difficulties

Similarly, only a sample of work on Conceptual Difficulties from around the world were mentioned in the above survey. From the preceeding references, research showed that there were common misconceptions about "force" held by research subjects around the world. Apart from references that were mentioned, studies on related concepts have also been conducted in countries where English is used as the language of instruction but is the second language to the learners. These include several African countries, India, Pakistan, Myamar and other countries which were former British colonies. However, not sufficient investigation has been carried out on these conceptual difficulties in South Africa, particularly among learners for whom English is a second language and the language of instruction.

Language Difficulties

Language Difficulties were investigated by several researchers and how these difficulties affected the studies and the understanding of their research subjects. The following researchers, amongst others were noted: Rollnick (1988) in Swaziland, Marshall and Gilmour (1990) in Papua New Guinea, McKinley et al (1992) about the Maori learners in New Zealand, Lynch (1996) about students in Tasmania and the Phillipines and various other researchers.

The present study therefore investigated both the Conceptual and Language Difficulties from a sample of learners who had studied or were studying mechanics.

2.7 SUMMARY

Many researchers worked on describing and elaborating what learning and understanding in science meant and how they could be explained. They proposed that background knowledge of the learners' preconceptions is vital to assist in assimilation or accommodation in the process of conceptual change in learning and understanding new information. Other researchers investigated how conceptual and language difficulties affected science learning and understanding among students. All these researchers suggested some possible remedies to the difficulties investigated and recommended how helpful and fruitful curricula could be developed to overcome the investigated difficulties and lead to better physics instruction.

CHAPTER THREE

INVESTIGATION

3.1 INTRODUCTION

3.2 RESEARCH STUDY OUTLINE

3.3 OBJECTIVES, HYPOTHESIS AND QUESTIONNAIRES

3.4 SAMPLE SELECTION

3.5 TECHNIQUES AND METHODOLOGIES

3.6 DATA PROCESSING

INVESTIGATION

3.1 INTRODUCTION

Many African learners have numerous difficulties in learning and understanding science in general, and physics in particular as stated in the Overview (1.1). Seretlo (1973) dwells extensively on several causes of these difficulties. The example of annual Senior Certificate results from several institutions, that is, the last pre-tertiary level of study in South African schools, which also is called Matric or Standard ten in South Africa, shown in Appendix 1, illustrate the problem the students have in science. This results sheet was taken from the Qwa-Qwa region which is partly urban and partly rural, and therefore the results could be assumed to be representative of Matric results of the African students in South Africa as a whole. These results further show a poor performance generally among students in physical science, with only a very few students, regarded as exceptions, scoring above 50% in the examinations. At the time of this study only when students scored above 50% in their examinations could they be readily accepted into tertiary institutions such as universities and technikons. Of those who make it into universities, much fewer than 50% of these students who register for a science degree manage to succeed in their first year physics courses.

The aim of this research study was to investigate the factors which contribute to the poor performance of most African students in physics, in particular, the difficulties of these African students and even teachers, in understanding some mechanics concepts. Moji and Grayson (1994) and also Grayson (1994b) emphasise the importance of lecturers knowing the background knowledge of the students about these concepts. It is only when ideas in the student's mind are known to the lecturer that it becomes easier for the lecturer to provide meaningful instruction on the physics concepts involved (Osborne and Freyberg 1985). It will thus be easier for the learners to assimilate or accommodate the concepts being introduced.

Among numerous difficulties in learning science experienced by these African learners, many of which were identified in the Overview, several were selected as variables, and only two of these difficulties were singled out to be investigated. These two difficulties were regarded by the investigator as the main hurdles in understanding mechanics concepts by the African students. These difficulties are: Conceptual and Language difficulties in mastering mechanics. Other difficulties that might pertain to this study, such as "school stay-away" and "class boycotts", were omitted since they were regarded as haphazard and inconsistent hinderances to learning in general. The investigator himself had similar difficulties such as those singled out while studying physics as a student at high school and university; while presently he is a University physics lecturer (appendix 20). The hypothesis of this work, which is divided into two above-mentioned themes, is stated in Section 3.3. The design of this study, its methodologies, data collection and analysis, and finally, the drawing of conclusions were processed, as proposed by Marks (1982), Leedy (1989) and Sanders (1996), to ensure both the validity and reliability in the research study being conducted.

3.2 RESEARCH STUDY OUTLINE

According to the literature surveyed, the design which needed to be followed in this a research study to yield valid and reliable results is outlined below:

1 The aims and objectives of the investigation
- aims and objectives
- hypothesis
- questionnaire design

2 Population and the samples selected
- population surveyed
- variables selected
- samples selected
  - reference group
  - pilot group
  - test or student group

3 Techniques and methodologies

data collection

data processing

report presentation

4 Recommendations and Conclusion.

3.3 OBJECTIVES, HYPOTHESIS AND QUESTIONNAIRES

The objectives and goals to be achieved in this study are outlined here. The hypothesis is proposed and the questionnaire tasks are discussed through which data were collected from the study subjects.

3.3.1 Objectives

The objective of this research study was to examine the understanding of several important mechanics concepts and to identify the possible influence of vernaculars of the African teachers and students on the learning of mechanics in the institutions visited.

First theme: Conceptual Difficulties

The first objective was therefore to investigate the theme of conceptual difficulties. The investigation covered the conceptualization of the mechanics terms: force, energy, power and momentum as a group; another group of terms whose conceptualization was studied, although not in great detail, was speed, velocity and acceleration.

Researchers around the world (Watts and Zylbersztajn 1981; Clement 1982; Halloun and Hestenes 1985; Arons 1989; Hestenes, Wells and Swackhammer 1992; Grayson 1994b) have shown that the existence of certain misconceptions results from students' self-constructed concepts about the world. "Motion is caused by the force applied" is one of many such misconceptions where the belief would be that:

1. Constant motion results from constant force
2. Motion will be in the direction of the force applied
3. The larger the force applied, the faster the motion.

This particular self-constructed preconception, labelled by most researchers as the "motion implies force" misconception, and which appears amongst students across the world, was investigated in the present research study among South African students using Task Two (see Appendix 5) in order to compare them with other international research subjects.

Another misconception appears in the understanding of speed, velocity and acceleration. This misconception is investigated by using Task Three (Appendix 6) among the subjects where they had to show the difference among the concepts of speed, velocity and acceleration of a ball thrown upwards.

Task 1 was constructed to investigate both themes of conceptual and language issues: how together they contribute to the difficulties in learning physics by African students (see Appendix 4).

Second theme: Language Difficulties

The second aim of this study, was to investigate the difficulty brought about by the apparent limitation of the vernacular in differentiating meanings of terms referring to important and different concepts in physics (Seretlo 1973; Rollnick 1988; McNaught 1994; Sanders and Sebego 1996), that is, the theme of Language Difficulties.

The language of instruction (English), which is not the first language for the African learners (where the learners often include both teachers and students), is often not well understood by both the teachers and the students. Books and study materials which did not originate in Africa might adversely affect African learners' understanding (Rollnick 1988; Marshall and Gilmour 1990; McKinley et al 1992; Inglis 1993; McNaught 1994; Sanders and Sebego 1996).

For African learners (both teachers and students), many related concepts being studied are called by one name (Sanders and Sebego 1996). Although most of them were distinct topics or concepts, they were undifferentiated in the vernaculars of these African learners, such as a Setswana term "Madi" which means "Blood", "Money", "Sperms" and "A relative" (Sanders and Sebego 1996).

Task 1 and Task 3 were used in the investigation of this theme of language difficulty, where a vernacular translation for the mechanics terms of the two groups of concepts was requested. The aim was thus to investigate the contribution of language to African students' difficulties with the learning of physics.

Language of instruction or language spoken in the process of teaching mechanics concepts is, however, affected by manners of communication, a particular "way" of talking about them which would expose the interrelationship between thought and mind (Vygotsky 1962; Seretlo 1973; Pines 1985; Sutton and Head 1985; Chomsky 1988) . The culture of the students who are taught needs to be understood since in teaching, appropriate thought carried by words of the language must be transferred (Vygotsky 1962; McKinley et al 1992; Nkopodi and Rutherford 1993). Grayson (1994a) noted how language intertwined with traditional beliefs led to misconceptions among students in a cross-cultural instructional setting. Second language used in instruction is, therefore affected by socio-cultural issues such as traditional beliefs, social orientations, political persuasions and religious convictions.

It is then noted that to successfully communicate the concepts in physics, cultural factors must be considered as stated by Thijs and Van der Berg (1994). Words taught do not just need translations that would be substitutions but cultural understanding as well as stated by McKinley et al (1992). The more different the two cultures are between which the translations must occur, the wider the gap between the thoughts conveyed by the words to be translate and hence the more difficult the final translation and understanding (Whorf 1973; Chomsky 1988).

In summary, the aim of this research study is to investigate the two above-mentioned themes, and how they contribute to the difficulties of African learners and teachers in South Africa in understanding several mechanics concepts.

3.3.2 Hypothesis

The hypothesis of this work can be phrased as follows for African learners in South Africa, where learners are both the teachers and students as the subjects of this study:

African learners' understanding of several mechanics concepts is affected by the following factors:

1. conceptual difficulties, common to learners around the world

2 use of a second language as the medium of instruction which cannot be translated directly into the vernacular of the students.

3.3.3 Written questionnaire and Interviews

Questionnaires and an interview protocol were developed that facilitated the investigation of the themes of this research study. The two themes that were investigated may seem to be separate from one another, but in some cases they turned out to be intertwined one with another.

Task One

The first task, which is labelled "Moshoeshoe's wars", shown in Appendix 4, is based on a historical fact where the Basotho king, Moshoeshoe, rolled boulders down on his enemies from the mountain top. Several questions were devised that related to this event and were to be answered by the research subjects to determine whether they could differentiate the mechanics concepts of velocity, speed, momentum, kinetic energy, force and power as boulders rolled or fell down from the mountain top and as they were rolled back to the top again. This task was used to investigate the students' conceptualization of these mechanics terms involved as the boulders rolled down. Also included in the task was an instruction to translate the relevant concepts into vernacular with the argument that if the concept is not clearly differentiated language-wise, it might not be clearly differentiated in conceptualization as well.

An extra question was incorporated in Task 1 involving translation; this question was only limited to the Pilot group. The question asked for the translation of a verse from the Bible, from the book of Ephesians chapter one, verses nineteen and twenty one (Eph. 1:19 and 21). The aim of this question was to see whether the students could differentiate words such as strength, strong, might and mighty, in their vernacular.

Task One, was used with the Pilot to investigate subjects' understanding of the physics concepts involved in the falling of the boulders, when the boulders are pushed uphill, and their understanding on the Biblical statement. It contained ten questions and was designed to identify both conceptual and linguistic difficulties, Task One - Rephrased contained only five rephrased questions from Task One; the minor question of the Biblical verse was excluded.

Task Two

The second task labelled "Quiz Question", is shown in Appendix 5. It was used to investigate the conceptualization of force on a ball, a stone or a coin thrown up from the hand, rising on its own until it comes to a stop at some position, then turning back downwards. This particular task has been used by many physics education researchers around the world to investigate the force conceptualization held by their research subjects (Watts and Zylbersztajn 1981; Clement 1982; Halloun and Hestenes 1985; Arons 1989; Halloun and Hestenes 1992; Grayson 1994b).

With this second task the investigator always explained clearly during the data collection sessions about how the arrows should be made to represent the directions and the sizes of the forces being indicated. The task was thus used to investigate the conceptualization of force by the subjects, and also to compare the responses of the local subjects with those of their counterparts around the world in this specific difficulty in which the students have constructed in their minds the ideas that:

1. Motion of an object occurs only when there is force applied.
2. The motion is only in the direction of the force applied.
3. The faster the motion, the larger the force applied.

Task Three

The third task labelled "Quiz Two" is shown in Appendix 6. It was designed to investigate the ability of the subjects to successfully differentiate the related mechanics terms speed, velocity, acceleration and force.

This third task was used to investigate at which pair of positions subjects thought the object had the same speed, the same velocity, the same accelerations and the same forces as the object travels up, slows down until it turns around and as it comes down. The task was further used to determine if the subjects' vernacular did successfully differentiate these concepts as different lest the subjects be misled into thinking the terms were synonymous and hence refer to the same concept. Each concept term had to be expressed in vernacular and in English. This third task therefore investigated both conceptual difficulties and the language difficulties experienced by the subjects with these concepts.

Interviews

Interviews were conducted in several institutions where they were accepted. Six teachers from the Pilot group, who were from different institutions, were interviewed. They willingly volunteered to be interviewed by the investigator whom they knew well. Some of these teachers had been taught first year physics by the investigator, and were quite open with him, except for one teacher, teacher Nts. She was quite sullen and refused to speak English. The interviews were conducted with individual teachers and each interview was recorded and fully transcribed; the interview transcriptions appear in seven appendices (Appendices 9, 10, 11, 14, 15, 16, 17, 18, 19, 22, 23 and 24). The interview with Mavlyn (Appendix 11) was to pilot the protocol. There were also interviews with groups of teachers after they had finished responding to the written questionnaire. The intention was always to have a few of the subjects at a time and ask them what they thought about the questionnaire they had just written. They would further explain why they answered the way they answered in the written results. However, interview sessions were not always successful. In Boitjhorisong, for example, the subjects were the four in-service teachers who once were students of the investigator, so they welcomed the interview much like an open conversation. Uniqwa, however, had twenty (20) subjects who were not willing to participate in, or answer any question. It took a long time before an individual subject answered a question asked repeatedly by the investigator. The fellow subjects looked sceptically at that subject. The effort to record the group interviews was not all successful.

In summary, the tasks are as follows:

Task 1: Moshoeshoe's wars for conceptual difficulties and translation for language difficulties. Original investigation on both the themes of conceptual and language difficulties.

Task 2: Quiz Question (Coin tossed up) for conceptual difficulties. Replication of the work of Physics Education Research workers around the world being presently applied to African students in South Africa.

Task 3: Quiz Two (Coin tossed up) for conceptual and translation difficulties for language themes being investigated. This is an original investigation.

3.4 SAMPLE SELECTION

Population

The population of interest in this study is composed of both African students and teachers evenly distributed across the face of South Africa, speaking more than nine major languages at home. As noted in the map (Appendix 2), the main separation of the communities according to language and culture is roughly accepted to be the mountain chain from the South to the North, called the Drakensberg, as indicated by thick black stripes. To the east of these mountains are the people of the Nguni group, who are Xhosa, Zulu, Swazi, Ndebele and Shangaan. The Sotho group on the west of the these mountains consists of Basotho, Batswana, Bapedi and the Venda people in the extreme North.

Variables

These African populations could further be classified into rural or urban, particularly since rural education differs greatly from urban education (McNaught 1994). The research field then extends over a population comprising nine languages and cultures and who are also either urban or rural, being eighteen groups in all.

Since samples on which the study should be carried out from this population should be as representative as possible, a central location needed to be identified where study subjects from diverse languages and communities overlapped.

Until 1994 in the Republic of South Africa, African people had two kinds of location where they were legally classified to stay according to the 1951 Bantu Authorities law. Africans working in towns could stay with their families in townships situated just outside the towns they served.

The townships had urban organizational structures including Education (such as: which children to attend which school, which school to teach which language group or even whose minibus taxi to transport children and teachers to which schools) . These structures were different from rural structures, where rural schools, including farm schools, are far to walk to and often unequipped with books, libraries and teachers. The townships are thus assigned: Sharpeville served Vereeniging, Soweto served Johannesburg, Gugulethu served Cape Town, Kwa-Mashu served Durban and so on. Africans who were not working in towns were pooled in remote rural areas named Homelands. There were ten Homelands in the Republic of South Africa distributed according to language and culture of the people of that area. Thus the Basotho were confined to Qwa-Qwa, the Batswana confined to Bophuthatswana, the Tsonga people to Gazankulu, Venda people to Venda and so on.

However, Soweto, for example, is a place that is very representative of all languages and cultures of the African communities, but Soweto is very urban, the most urban of all townships in South Africa. A more ideal location the investigator could identify, as a person who had stayed in various places in South Africa, was a place which was neither very rural nor very urban, namely the Maluti Highlands, in the North-East of the Free State province, where there are many schools in Phuthaditjhaba and in Witsieshoek, and also where most of the African languages in South Africa are spoken. Confirmation of this last point is that the investigator originates from this area of Maluti Highlands and speaks, writes and reads several of the eleven major languages of South Africa.

Variables to the procedures of this study which could affect the results adversely if not kept constant or excluded while the investigation of the mentioned themes was carried out, were:

1. Class boycotts by students which have, in the past years during the period of this study been so rife and notably disturbed students' learning in general across the whole country.

2. "Chalk downs" by teachers have also been very common for the last several years which resulted in many poor school results.

3. Socio-political issues such as the cases of students who are taught by the poorly trained and qualified African teachers, those who come to school to learn while not having had a single meal for the previous two days or those who had their house burned the previous night, or even socio-economical issues where students wish to continue to learn while they are told to clear off from the class room since their parents do not have money to feed them or buy them the required uniform to keep them at school.

4 Socio-economical conditions affected (McNaught 1994) most Africans students more adversely at the secondary schools than at tertiary levels. Students in tertiary institutions were better funded than those at secondary institutions. Students in tertiary institutions would be more stable to work among than those at secondary institutions.

The above-mentioned variables affected the secondary schools mostly while the variables were quite rare among students at Colleges of Education, Teachers Training Institutions and Universities. These institutions became venues where the populations turned out to be more stable and consistent for the research study.

3.4.1 The Pilot group:

Teachers, pre-service and in-service

The Teachers comprising the pilot research samples were mainly selected from the populations of the institutions mentioned below as the most stable ones variable wise. The institutions are Colleges of Education and Universities. Other institutions were also visited and used as research sites, but because of the effect of the variables mentioned previously, results obtained from these institutions were only used as pilot data, not included in data tables.

Colleges of Education:

The institutions from which the Teacher pilot study subjects samples were drawn were:

1. Tshiya College of Education, a teacher training college in Witsieshoek which had been famous from 1962 since it produced a great number of good teachers spread across the country. Tshiya has lecturers of mixed backgrounds and nationalities. Most of these lecturing staff are graduates with either a degree and a teaching diploma or teaching degrees. White authorities have always run this college since its inception in 1962 although it is in the heart of the so-called Bantustan. Tshiya is well equipped with laboratories and libraries for training teachers who are to teach pre-university students.

2. Boitjhorisong In-Service Training Institution is an in-service training institution in Qwa-Qwa. It serves to re-equip teachers who have been in the field for a long time, who from time to time need to be upgraded with the new techniques and content in their fields of teaching. Boitjhorisong is particularly known for serving the science teachers of this region well due to the well-qualified science staff, well-equipped laboratories and well-supplied library.

3. Bonamelo College of Education is an institution in Phuthaditjhaba. It is a relatively new institution which has some well trained science teachers who have organized a number of public demonstrations of science projects. It is a popular institution that accepts all groups of black students from all places in the country (other institutions were limited to certain groups only).

4. Sefikeng is a College of Education also in the remote part of Qwa-Qwa that had always been populated with youth who came from an education and teaching culture. Most of them knew no occupation or career other than teaching as the desired and ultimate reward of the hard working learned people. This is a relatively new institution in age, opened in the late eighties. Most teachers are graduates, and at the time of this study, the institution was still working hard to attract the best staff, libraries and laboratories.

Sefikeng is situated at the foot of the most beautiful Mount aux Sources mountain.

5. Taung College of Education is an institution situated in Taung. There were five subjects in this college that responded to the study questionnaire. They were subjects of similar study level as those of the subjects from North-eastern Free State.

6. "Teacher educators" is a group of lecturers who teach physics at some of the above-mentioned institutions. Two were in Tshiya Teachers Training College, three in Boitjhorisong and one in Bonamelo. They are the teachers of the pre-service teachers. They have been teaching for some time. The aim to have them as subjects in the study was to observe how much they differ from their students in answers.

There were other institutions that were visited outside the area mentioned, namely, Science teachers at Moqhaka High in Sebokeng, University of Manchester and Fezeka Secondary School in Gugulethu, mainly for the sake of pilot study and informal validation.

University

1. Uniqwa is a campus of the University of the North, a university which from the sixties was erected for some groups of Africans in South Africa, the groups being SOVENGA. The word is made up as follows: SO is for SOthos, VE is for VEndas and NGA is for TsoNGAs. The campus in Qwa-Qwa was built with the idea of educating Sotho groups of students even though it is not like that any longer - Ngunis, Asians, Coloureds and Whites are all there now. It is an institution that is well equipped for undergraduate science, which is well taught by professors. Physics was taught by a lecturer and two professors at the time of this study.

Pre-service teachers trained in this university must study at least first year physics if they are going to teach physical science at schools or colleges.

Besides the Pilot group, there were two other groups that were involved for comparison of the results of the investigation, namely, the Reference group and the Test or Student group.

3.4.2 The Reference group:

Physicists and language experts

There were two kinds of subjects in the Reference group: those for the theme of conceptual difficulties and those for the theme of language difficulties.

Conceptual Difficulties

The Reference group for the theme of conceptual difficulties consisted of authorities in the subject under investigation. They were lecturing staff members in four universities. Two members of this Reference group were from the Physics Department of the Qwa-Qwa campus of the University of the North, two were from Science Education in the Education Technology Department of the University of Manchester, three were from the Physics Department of the University of Western Cape and six were from the Physics Department of the Pietermaritzburg campus of the University of Natal.

They were a group which determined whether the questions asked in the questionnaire were really determining what was being investigated, i.e. whether the questions asked were really valid questions. They were the subjects whose responses on the questionnaire were pooled together and were regarded as correct if they were unanimous. It was from their responses that the responses of the other groups were marked correct or incorrect. This Reference group acted as a validating group.

Language Difficulties

The Reference group for the theme of language difficulties was different from the Reference group for conceptual difficulties. The former consisted of university physics lecturers and post-graduate physics students from various universities whose vernaculars are any of the African languages in South Africa. From the University of the North there were submissions of Sesotho, Sepedi, Tsonga and Venda. From the University of Zululand came Zulu submissions, from the University of North-west, Setswana submissions and from the University of Western Cape, Xhosa, Venda and Afrikaans submissions and Zulu from the University of Natal.

3.4.3 The Student group:

The physics first year students

The first year physics students who were studying at the Pietermaritzburg campus of the University of Natal in the first semester of 1996 were taken as experimental or focus subjects in the study. They were 153 subjects in all. Classified according to language, 82 had English as their home language, while 76 had various African languages in South Africa as their home languages. These subjects attended two different first year physics classes, namely 110B which is a terminal physics course taken mostly by students taking biological sciences as their majors and 110S which is taken by those who have physics as their major and those who study for engineering. 94 subjects were in 110B lectured by Prof 1 and 59 subjects were in 110S lectured by Prof 2. Thus each class consisted of students who were English speaking (White and Indian) and African vernacular speaking who were all exposed to the same material in the same way.

These subjects were used in two different ways: (1) to compare the results obtained by students of different ethnic groups at the same level of study, in the same institution while lectured by the same person (2) African students in this Student (Test) group had their translations compared with those of the Pilot group to further investigate the effect and influences of the language issues

(Sanders and Sebego 1996). This group was thus used to provide a comparison with the results obtained from the Pilot group. It is called the Student or Focus group because all students of differing language groups in each course would have received the same formal instruction in mechanics, in other words the variable of teaching received was controlled.

3.5 TECHNIQUES AND METHODOLOGIES

Physics and physical science lecturers at different institutions were contacted by the investigator who requested research time with their students. The investigator always promised that the time would not be more than one hour. He requested a group of twenty of the subjects to participate where possible. It ought to be those that have already learned mechanics. The lecturers contacted were always cooperative (if there was no boycott or stay-away in their institution).

Data collection - written responses

At each institution, written tasks were handed out to the subjects individually with ample introductory explanation from the investigator as to why such tasks were being asked of the subjects, and what was expected of them. It was after all written responses were collected that interviews were requested from the subjects in each institution.

From the extensive lecturing experience of the investigator, he has found that a close and intimate introduction wins openness and positiveness among African students, while the students would otherwise probably reject the unknown stranger.

Task One (Moshoeshoe's wars) was always given out first in all institutions. In this historical event, application of physics principles was interestingly accomplished. Pilot subjects were encouraged to translate the Biblical verse mentioned. It should be noted that without such frequent encouragement throughout the process, subjects easily lost interest. When they had finished their written responses, an open conversation or a "chat interview" would follow with the whole group, lasting for about ten minutes or more. From the investigator's experience, few African students would easily be interviewed by a stranger. They turn out passive and timid, especially the lady subjects.

Although there were instructions that were supposed to be followed in performing this task , the investigator deliberately did not emphasise these instructions so that the subjects were also tested on whether they noticed these important instructions. Translations into vernacular were requested in these instructions.

Task Two (Quiz Question), asks for the forces on the ball from the thrower's hand. The investigator always stressed the following points: (i) that this is a simple matriculation question, (ii) they could all easily answer it, and (iii) they should neglect air friction. He walked freely amongst the subjects in order to make them feel as free as they possibly could. Again at the end of the written work, the conversation interview was conducted, with open participation which was normally very limited if freeness had not been achieved between the investigator and the subjects.

Task Three was then issued as a continuation of Task Two, only that here the Physics concepts were to be expressed in vernacular. The investigator walked among the subjects stressing and reminding them how important it was to indicate the meaning of the particular concept in their own vernacular.

Data collection - Interviews

The investigator asked several teachers in the Pilot group to be interviewed. They had already been teaching physical science at matric level for more than five years, some even for more than ten years. They were selected from the area of this study; teacher Mm and teacher Ma were from a school which is regarded to be strong such that there are times when it produces some "C" symbols in their matric results (Mampoi Senior Secondary), teacher Mk was from the school regarded to be average in its performance, "not so strong not so weak" (Sebabatso Senior Secondary) teacher Nts was from a new school not yet classified and teacher Paul is a subject adviser in the district of the area of the study.

These interview subjects were contacted by phone and were requested to respond to some interview questions concerning physics concepts of the mechanics which they teach and which they have studied successfully at the universities; however, teacher Nts was sent the message through teacher Paul. The Task One with five questions, the task which was given to Student group in this study, contains the questions which were used in the interview questionnaire. Further particulars of the interviews appear with the actual interview transcripts in Appendices 9, 10, 17 and 18.

It was important to use a tape recorder in all of the interview sessions in order to keep an accurate record of the subjects' comments. Most of these conversations are very interesting, particularly if the subjects were free and open with the investigator. Although it is advisable to have the opinions of the subjects individually or in small groups, in some institutions subjects would only be very free if they were all together, addressing and responding to the investigator, while in the small groups they are shy and reserved. It was therefore advantageous both for the investigator and the subjects to have the conversational interviews together rather than as individuals or in small groups. The transcripts of these interviews in groups appear in Appendices 14, 15 and 16.

The attitude of the investigator would prove to be the determining factor as to whether the research project is approved by the subjects. During the bitter times of Black-White conflict in South Africa, when the investigator and his colleagues were students, they were one day forced to be subjects for a questionnaire of a white visitor in their technikon. All the subjects disapproved of the disseminated questionnaire, they bitterly and deliberately gave incorrect responses. The sign of good acceptance by the subjects will in almost all institutions be indicated by a general chatting and consultation with the investigator about issues like further studies in physics. Some subjects invited the investigator to visit their institutions to address them about science, not only to come when he needed to collect some research data.

3.6 DATA PROCESSING

Data collected from among all the subjects, i.e. Pilot group and Student group, which consisted of written responses on the task sheets and the conversational interview responses which were transcribed from the cassette, was later reviewed for the sake of deeper examination and interpretation. The responses from the subjects, that were arranged in several tables, were analysed as follows:

For Tasks One, Two and Three, which investigated the first theme of conceptual difficulties, the unanimous responses from the Reference group were regarded as "correct" answers and hence regarded as a" marking memorandum" for the first theme of conceptual difficulties being investigated. It was against this "memorandum" that the questions were corrected from both the Pilot group and the Student group; the responses were either correct or incorrect; however, both the written results and interviews were interpreted.

The responses to tasks One and Three were analyzed as the second theme of language difficulties being investigated. Translations were used to show how the language difference between mother tongue and the language of instruction causes difficulties, as emphasised by Pines (1985) in the argument that language serves both thought and language, Rutherford and Nkopodi (1990) who state that African languages make it difficult to transmit thoughts and meanings in western sciences, Chomsky (1988) lectures where language in knowledge acquisition was discussed and as in Sanders and Sebego (1996) where the language problems were those of students whose home language was Setswana . The Reference group in this theme was made up of seven African physicists from various Historically Black Universities in South Africa. Besides, the investigator knowing most of the African languages in South Africa through which the subjects were to respond, informal consultations were done with people of more authority in each individual language. Responses were interpreted.

Interpretations of these written responses, that is, what the investigator understands the responses to mean, followed the written responses. The interview or conversation transcript also followed, again followed by the investigator's interpretation.

After all the data were collected, tabulated, interpreted and analysed, conclusions were drawn as to what factors might contribute to the difficulties of African students in understanding physics.

CHAPTER FOUR

CONCEPTUAL DIFFICULTIES

CONCEPTUAL DIFFICULTIES

4.1 INTRODUCTION

The data which was collected concerning the conceptual understanding of several mechanics terms from both the Pilot and Student groups, were recorded in this chapter. Several concepts in physics, for most African students and even teachers, appeared to be closely related although they were distinctly different. Force, energy, momentum, power and impulse, together were in a group where they were easily confused; velocity, speed, acceleration form another such conceptual confusion group. Physics education researchers around the world have worked widely among students in the investigation of the conceptualization of most of these physics terms, as was indicated in the literature survey. In Chapter Two, the literature surveyed showed how incorrect students' understanding of physics all around the world may be, such as thinking force would always be in the direction of motion. In this study the responses of African subjects in South Africa, both in the Pilot and Student groups, were observed and compared with others who were not African but were in the same level of study as Africans in the Student group and also with their overseas counterparts, whose performance was mentioned in the literature by the researchers.

In this study, the investigator wished to determine the effectiveness of the training of student teachers (in teachers training colleges) in physics, as well as the training of students of freshman physics in the University of Natal, Pietermaritzburg. If the understanding of physics of these learners was correct, they would pass correct physics ideas on to their future students; if they as teachers would have misconceptions about physics, their students would be poor in pre-university physics.

Three tasks were used in the investigation of the theme of Conceptual Difficulties, namely:

1. Task One (Appendix 4), Moshoeshoe's wars, which investigated the mechanics quantities the boulders gained or imparted to their neighbours as they rolled and the quantities the men or boys needed to be able to roll them. A comprehensive

elaboration of this task was done in section 3.3.3. The Pilot group was given the questionnaire for piloting while a revised version was given to the Student group.

2. Task Two (Appendix 5), which investigated the forces on a ball thrown up as it rose and fell. This task was also discussed in section 3.3.3.

3. Task Three (Appendix 6), also discussed in section 3.3.3, was used to investigate the speed, velocity and acceleration of a ball as it was thrown up and fell back down.

The responses which were collected from the study subjects were marked as correct or incorrect in comparison with the responses which were given by the Reference group, who determined the validity of the questions in this research study.

Written data were collected from the subjects of the Pilot group . Interviews were also conducted where convenient, with some teachers in Qwa-Qwa in the Pilot group. Where energy appeared as a response in Task One, unqualified as to which kind of energy was meant, it was always taken as kinetic energy since most of the subjects said it was kinetic if they were asked to qualify it. In this chapter the results and the interpretation of both the written data and interviews are presented, first from the Pilot group and then from the Student group for the main research study, followed by a summary.

The three tasks referred to above were handed out to the subjects, one task at a time. Several announcements were made. Subjects were told to neglect air friction; they were asked not to be close to their friends in order to avoid the neighbour's influence on their work. It was explained intermittently with patience the meaning of the research they were participating in: that they were not being tested as in an examination, to pass or fail, and that therefore, they had to honestly present their real understanding of these concepts and not their neighbours' understanding.

4.2 ENTITY (OR THE MECHANICS QUANTITY) IN AND ON BOULDERS

Task 1 (Appendix 4) was an historical phenomenon where Moshoeshoe applied physics principles to conquer his enemies in the wars during the Lifaqane (general wars of extermination) times in the 1840s in Lesotho. From the top of Thaba-Bosiu boulders were rolled down on the enemy who were almost at the top of the mountain, trying to catch up with Moshoeshoe whom they were pursuing.

Boulders became "stronger" as they fell farther and farther down the mountain, killing more of the enemy with more and more "strength". It was here therefore investigated what it was, or what entity it was, that the research subjects thought that the boulders gained from the point of view of physics concepts as they rolled down, becoming "stronger and stronger". Although answers for Task One were required both in English as the medium of instruction and in the vernacular, analysis of conceptual difficulties was only done for on the answers given in English. Vernacular answers will be discussed in the following chapter, Chapter Five, on the investigation of language difficulties.

The Reference group on Conceptual Difficulties was introduced in Section 3.4.2. It consisted of several Physics lecturers and professors from universities inside and outside South Africa. The responses to Task 1, and Task 2 from this Reference group were considered as the "correct" answers and constituted the memorandum by which the responses of the study subjects were to be marked. The responses of this Reference group on the modified Task 1 (Appendix 4) are as follows:

REFERENCE GROUP RESULTS

1 As boulders rolled down, which quantity or quantities did they gain?

Responses: Speed, Velocity, Momentum and Kinetic Energy.

2 When a rolling boulder collides with the neighbouring stationary boulder, which quantity or quantities does it impart to a stationary boulder?

Responses: Momentum and Kinetic Energy

3 Some falling boulders can kill a man. For such a boulder to kill a man it must have a large amount of ......

Responses: Momentum and Kinetic Energy

4 Some small boys could not even move the boulders; in terms of mechanics concepts, in what way are the boys different from men?

Responses: Boys apply or exert insufficient force

5 Man X and man Y are rolling identical boulders up the mountain. Man X arrives at the top ten minutes before Y. Describe the differences between man X and man Y rolling boulders in terms of as many mechanics concepts as you think are relevant.

Responses: Man X generates or expends more power.

Although on the first two questions the members of this group were unanimous in their responses, some of them (two) used weight as a response in question 3. Question 4 had a number of the members of this group differing in at least two aspects of this question: while force was the quantity needed three of these members said energy while one said power. Among those who rightly said force, one professor said the boys did not "have" enough force while the rest rightly said not sufficient force was "applied" or exerted. However the above responses were accepted to be "correct"

On Task 2, there was a general consensus by the whole group that if the air resistance was to be neglected, there was only one force acting on the ball at all three positions 1, 2 and 3, that is, the gravitational force acting in the downward direction.

PILOT GROUP RESULTS

4.2.1 As boulders rolled down, they gained... (the entity or mechanics quantity)

When one looks at a boulder leaving the top of a mountain, it can be seen to be becoming "stronger" and "stronger" as it tumbles lower and lower down the slope. It can be very dangerous for one to be in its way when it is much lower than when it is still higher. It gradually gains some entity to render it "stronger". What can this entity be called? There were four answers that were "correct" according to the Reference group, namely speed, velocity, momentum and kinetic energy. The responses of the Pilot group subjects from the institutions indicated in Chapter Three are shown in Table 4.1 (Task 1, Question 1).

TABLE 4.1

Responses to the question "As boulders rolled down, they gained..."

INSTITUTION	N	SPEED	MOMENTUM	ENERGY	VELOCITY	OTHER
		%	%	%	%	%
B	4	25 (1)	75 (3)	-	-	-
UNQ 1	13	23 (3)	23 (3)	38 (5)	-	15 (2)
T 2	20	25 (5)	40 (8)	20 (4)	-	15 (3)
T 3	20	5 (1)	45 (9)	40 (8)	-	10 (2)
BN	43	31 (13)	14 (6)	21 (9)	2 (1)	33 (14)
UNQ 2	6	17 (1)	33 (2)	33 (2)	-	13 (1)
TOTAL	106	24	31	28	1	22
%	100	23	29	26	1	21

N : Number of subjects
B : Boitjhorisong
BN : Bonamelo
T3 : Tshiya College - 3rd year
OTHER: Answers different to those expected
UNQ :University of the North
T2 :Tshiya College - 2nd year

Results

On the falling boulders question there were many subjects who gave correct answers for the entity that was being gained as boulders fell, namely speed, velocity, momentum and kinetic energy. Although some subjects did not specify kinetic energy in particular, but only mentioned energy, it was accepted as correct in this case (Table 4.1).

79% (88/106), were able to give one out of four correct answers, where 23% (24/106) stated that speed was gained, 29% (31/106) said momentum was gained while the rest, namely the final 26% (28/106), said kinetic energy was gained as boulders were falling down and 1% (1/106) said velocity. 21% (22/106) fell under "OTHER" which was not correct in that they mentioned various other terms such as acceleration, force, vigour, power, strength and anger. Those that were left blank were also counted among the incorrect. These terms which were different from what was expected, were all carrying much the same meanings, although they were not completely synonymous. They could each be translated as matla/amandla (in Sotho/Nguni) by those who did translate, while most subjects also translated energy and momentum as matla/amandla (see section 5.2.1).

It is further disturbing that one particular institution among all those who presented the incorrect answers, Bonamelo, had 33%(14/43) of its subjects not being correct as compared to the average of 15% of other institutions. Tshiya 3 had the lowest of all these low percentages, 10% (2/20).

Comment

The responses to this question were not difficult in that there were four of them that were correct, namely speed, velocity, momentum and kinetic energy. These concepts were, however, connected with, or were all related to speed. When speed is gained, so are momentum and kinetic energy as well. However, it was interesting that the incorrect responses were also thought to be meaning matla/amandla in a different sense. Of the 106 subjects, only 5 subjects gave more than one term in their responses which were: 2 gave energy and power; 1 gave speed and power and 2 gave speed and momentum. All responses were thus incomplete; some were correct though incomplete, some incorrect. However, in 101 of all 106 responses only one word was given as the response as shown in Table 4.1.

Interviews

Teacher Mm's extract (Appendix 18)

I : ... As the boulders roll down the mountain what quantity or quantities do they gain?

Mm :They gain momentum.

I :They gain momentum, and anything else?

Mm :Of course energy.

I :Which kind of energy? You know physics says even heat is energy.

Mm :Kinetic energy.

I :Anything else?

Mm :They gain force.

I :You say they gain force, anything else?

Mm :I think that's all.

Teacher Ma's extract (Appendix 17)

I :Now question one: as boulders rolled down, which quantity or quantities did they gain?

Ma :They gained acceleration.

I :Ok, they gained acceleration, and something else?

Ma :I can say they also gained momentum.

I :Momentum - yes, what else?

Ma :I think that's all that I can give.

Comment

In both interviews it was noted that the subjects were satisfied to give one term in their responses. With several "what else" persuasions teacher Mm gave two more terms and teacher Ma gave one more. Teacher Mm gave energy as a response and only qualified it as "kinetic" only after being asked to do so. Teacher Ma gave acceleration as a response without hesitation. She had been teaching for more than ten years; was she seriously incorrect or was she mixing up some concepts? Despite these incorrect responses, it was encouraging to note that there were correct responses from these Pilot group members.

4.2.2 Boulders fell on the enemy with... (the entity or the mechanics quantity)

Boulders were rolled down from the top of Thaba Bosiu and would "rain" on the enemy. This quantity the boulders fell on the enemy with, was identified as momentum and kinetic energy, as validated by the Reference group. Table 4.2 below shows the responses of the Pilot group.

TABLE 4.2
Boulders fell down on the enemy with ... - responses

INSTI-TUTION	N	POWER	FORCE	SPEED	IM-PACT	EN-ERGY	M	OTHER
		%	%	%	%	%	%	%
UNQ	20	25 (5)	25 (5)	30 (6)	-	-	-	20 (4)
B	4	-	50 (2)	25 (1)	-	-	-	25 (1)
BN	42	19 (8)	40 (17)	14 (6)	7 (3)	-	5 (2)	14 (6)
TAU	5	-	60 (3)	20 (1)	-	-	-	20 (1)
TS	6	17 (1)	17 (1)	17 (1)	17 (1)	-	17 (1)	17 (1)
T 3	19	21 (4)	31 (6)	21 (4)	5 (1)	5 (1)	-	16 (3)
T 2	21	5 (1)	43 (9)	25 (5)	5 (1)	11(2)	-	14 (3)
TOTAL	117	19	43	24	6	3	3	19
%	100	16	37	20	5	3	3	16

UNQ :University of the North
BN :Bonamelo
TAU :Taung
M :Momentum
OTHER: Answers different from expected ones

B :Boitjhorisong
P :Power
TS :Teacher educators
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd year

Results

While the "correct" responses according to the Reference group were that the boulders fell on the enemy with momentum and kinetic energy, the results are shown in Table 4.2, where 37% (43/117) responded that boulders fell on the enemy with force, 21% (24/117) responded that boulders fell with speed, 16% (19/117) responded that boulders fell with power, 5% (6/117) said impact, 3% (3/117) said energy and 3% (3/117) said momentum. 16% (19/117) supplied responses different from those that were expected such as strong, effort, strength, movement and some that were left blank.

Comment

The quantity the boulders fell on the enemy with was apparently matla/amandla to African people; as seen in section 5.2. If the boulder did not "have" sufficient matla/amandla the enemy could survive, which is what was not wanted. This matla/amandla concept needed translation from mother tongue understanding into English, that is, a" reverse translation", where this concept translation would not only convey the literal meaning but also the understanding of a concept to the student (Vygotsky 1962; Head and Sutton 1985; Chomsky 1988; Rutherford and Nkopodi 1990). The results given by the Pilot group here were therefore all translations of matla/amandla, namely: impact, energy, force, power and momentum. All these words are translated as one word: matla by the Sotho groups and amandla by the Nguni group.

4.2.3 Each boulder colliding with its neighbour imparts ... to it (the quantity)

As boulders tumbled down the slope, they collided with stationary boulders that could not reach the top of the mountain. As they collided, the moving one imparted some quantity to the stationary boulder, possibly setting it rolling down as well. The correct response according to the Reference group was that kinetic energy and momentum were imparted to the stationary boulder.

Results

The results of the Pilot group are presented in Table 4.3. 21% (24/116) of the subjects said the rolling boulder imparted momentum to its neighbour, 17% (20/116) said the boulder imparted energy (accepted to mean kinetic), 13% (15/116) said force, 5% (6/116) said power and 2% (2/116) said matla untranslated, while 41% (47/116) responded with answers different from those expected such as strong, sound, movement, including those that were left blank.

TABLE 4.3

Each boulder colliding with its neighbour imparts ... (a mechanics quantity)

INS	N	Power	Energy	Force	M	V	MA	OTHER
		%	%	%	%	%	%	%
UNQ	20	-	30 (6)	5 (1)	15 (3)	-	10 (2)	40 (8)
B	4	-	50 (2)	-	50 (2)	-	-	-
BN	43	7 (3)	2 (1)	16 (7)	19 (8)	-	-	56 (24)
TAU	5	20 (1)	40 (2)	20 (1)	-	-	-	20 (1)
TS	6	17 (1)	33 (2)	17 (1)	33 (2)	-	-	-
T3	19	-	26 (5)	5 (1)	26 (5)	5 (1)	-	37 (7)
T2	19	5 (1)	11 (2)	26 (4)	26 (4)	-	-	37 (7)
TO	116	6	20	15	24	1	2	47
%	100	5	17	13	21	1	2	40

INS :Institution
N :Number of subjects
BN :Bonamelo
M :Momentum
V :Velocity
MA :Matla
OTHER:Answers different to the expected

UNQ :University of the North
B :Boitjhorisong
TAU :Taung
TS :Teacher educators
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd year
TO :Total

Comments

Subjects who gave momentum and energy as answers are regarded as correct; there are 41% (47/116) of them. 20% (23/116), answered with force, power or matla. All the subjects gave a single term response or answer for this question except 6 responses which contained more than one term. 1 was correct and complete; 2 gave momentum and speed; 1 momentum and friction; 1 momentum and force and 1 power and force which are all partly correct and partly incorrect. Apparently they had difficulty translating matla/amandla, and they ended up with force or power, and some could not even translate matla but left it as it is.

Interviews

Teacher Mk's extract (Appendix 9)

I :When the boulder rolls down, it collides with the stationary other boulders that are nearby. Which quantity does this rolling boulder impart to the standing ones down the mountain?

Mk :It imparts momentum.

I :Ok, momentum, is it only momentum?

Mk :It imparts the energy as well.

I :Ok, anything else.

Mk :And then the force.

I :Ok, it imparts the force, anything else?

[Quietness].

Teacher Paul's extract (Appendix 10)

I : ... When boulders roll down, they collide with other neighbouring stationary boulders, what quantity do they impart?

Paul :Energy.

I :You don't want to classify that energy? Which kind of energy?

Paul :Kinetic energy.

I :Kinetic energy and anything else? Would there be any other quantity?

Paul :As far as I think, it is all.

Teacher Mm's extract (Appendix 18)

I : ...When the boulder collides, what does the moving boulder impart to the stationary boulder?

Mm :In collision obviously there is conversion of energy.

I :It gives energy, what kind of energy? and anything else besides?

Mm :Momentum and acceleration.

I :Anything else, you said energy, momentum and ....[interruption].

Mm :And some force.

Comment

These subjects were satisfied to give only one term as a response until the investigator said: "Anything else?" then followed other concepts. One wondered if the terms were just guessed or why the subjects did not just give them initially. As more probing came with the "anything else" from the investigator, more incorrect responses followed from the subjects, responses such as acceleration and force.

4.2.4 To kill a man a boulder must fall on him with much ... (a mechanics quantity)

To win the war, the enemy must be killed. What is it that the boulder must impart or transfer to the enemy in order that the enemy man will be killed? The more of this entity the boulder has, the easier it will be to kill men of the enemy. Kinetic energy and momentum are the right answers, according to the Reference group.

TABLE 4.4

To kill a man a boulder must fall on him with much ...

INSTI-TUTION	N	POW-ER	EN-ERGY	FORCE WEIGHT	IM-PACT	SPEED	M	OTHER
		%	%	%	%	%	%	%
UNQ	20	20 (4)	15 (3)	35 (7)	-	15 (3)	10 (2)	5 (1)
B	4	50 (2)	-	25 (1)	25 (1)	-	-	-
BN	43	25 (11)	19 (8)	21 (9)	-	16 (7)	-	19 (8)
TAU	5	20 (1)	-	60 (3)	-	20 (1)	-	-
TS	6	-	-	67 (4)	-	17 (1)	17 (1)	-
T3	19	21 (4)	5 (1)	37 (7)	5 (1)	16 (3)	5 (1)	11 (2)
T2	19	37 (7)	-	47 (9)	5 (1)	5 (1)	-	5 (1)
TOTAL	116	29	12	40	3	16	4	12
%	100	25	10	35	3	14	3	10

UNQ :University of the North — N :Number of subjects
B :Boitjhorisong — BN :Bonamelo
TAU :Taung — TS :Teacher educators
T3 :Tshiya College - 3rd year
M :Momentum — T2 :Tshiya College - 2nd year
OTHER: Answers different from the expected

Results

The results are presented in Table 4.4. 10% (12/116) said the boulder must fall with kinetic energy to kill a man, 3% (4/116) said momentum. They are the 14% (16/116) which are correct. However, 3% (3/116) said impact, 35% (40/116) said force, 25% (29/116) said power, 14% (16/116) said speed and 10% (12/116) answered with the answers different from what was expected, answers such as effort, action, work and pressure. Some were left blank or unanswered.

Comments

In everyday communication the needed entity a boulder must have to kill is heaviness. Weight which is a force, dominated the responses as the necessary quantity the boulder must have to be able to kill a man. However, weight, being a force, cannot be intrinsically possessed, hence the boulders cannot be "having" it. Nevertheless, all the responses except speed are translations of matla/amandla. The 10% (12/119) who gave the unexpected answers mentioned above such as effort and the others, were probably reluctant to keep repeating words already mentioned as others did. However, the words given were still translated as matla/amandla (Section 5.2).

Interviews

Teacher Mk's extract (Appendix 9)

I : ... Some falling boulders can kill a man, for such a boulder to kill a man it must have a large amount of ... some quantity. We must give an appropriate quantity even in our language [long quietness].

Mk :It must be a large amount of force.

Teacher Mm's extract (Appendix 18)

I : ... Such falling boulders can kill a man, for such a boulder to kill a man it must have a large amount of some mechanics quantity. What mechanics quantity should it be?

Mm :A large amount of energy and force, impulse - that's enough.

Teacher Paul's extract (Appendix 10)

I : ... Some falling boulders can kill a man. For such a boulder to kill a man it must fall on a man with a large amount of some quantity, what would that quantity be?

Paul :Shall we say force?

I :Anything else? Would it only be force?

Paul :Momentum.

I :Ok, you say force and momentum, what is force in your language?

Teacher Ma's extract (Appendix 17)

I : ...Some falling boulders can kill a man, for such a boulder to kill a man it must have a large amount of some quantity, what would that quantity be?

Ma :It can be mass, it can be its velocity, it can be kinetic energy.

Comment

The majority of subjects interviewed thought that to kill a person, the boulder must fall on this person with a large amount of force. This question, however was posed very poorly by the investigator to the subject: what quantity must it have? This means the quantity will be carried by this boulder to kill the man, it sounds as if it should be a quantity intrinsic to the boulder. When the questionnaire was administered to the Student group it was reworded (see Appendix 4).

4.2.5 Men rolled the boulders up faster than boys, because ...

In Moshoeshoe's empire, it was the duty of all the males to roll the boulders back to the top of Thaba Bosiu during peace time. This was achieved by arranging it to be a game: for rolling large boulders fast over some upward distance, a person would win a prize. Evaluation for the prize was as follows: the larger the boulder, the more the points that were won; the faster the boulder was rolled, the more the points that were won; the longer the distance over which the boulder was rolled, the more the points that were won. Although men would roll boulders faster than boys to win the prize, there was a reason why they could manage to roll them faster than boys: men had ample quantity of this entity which boys lacked. What could it be? The right answer for the reason that men were able to roll boulders faster was that they applied more force than boys.

TABLE 4.5

Men rolled boulders faster than boys, because ... - responses

INS	N	Power	Energ	Force	FIT	MA	STR	OTHER
		%	%	%	%	%	%	%
UNQ	20	10 (2)	40 (8)	20 (4)		10 (2)	5 (1)	15 (3)
B	4	50 (2)	-	25 (1)	-	25 (1)	-	-
BN	43	40 (17)	21 (9)	12 (5)	2 (1)	7 (3)	-	19 (8)
TAU	5	40 (2)	-	40 (2)	-	-	-	20 (1)
TS	6	33 (2)	-	33 (2)	-	-	-	33 (2)
T3	19	26 (5)	31 (6)	16 (3)	11 (2)	-	-	16 (3)
T2	19	26 (5)	39 (7)	16 (3)	5 (1)	11 (2)	-	5 (1)
TOTAL	116	35	30	20	4	8	1	18
%	100	30	26	17	3	7	1	16

INS :Institution
N :Number of the subjects
BN :Bonamelo
FIT :They were fit
MA :Matla
STR :Strong
OTHER:Answers different from those expected

UNQ :University of the North
B :Boitjhorisong
TAU :Taung
TS :Teachers
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd year

Results

The results are shown in Table 4.5. 30% (35/116) answered that men had more power, 26% (30/116) responded that men had more energy, 17% (20/116) answered that men had more force, 7% (8/116) responded that men had more matla (not translated), and 3% (4/116) said men were more fit than boys. 16% (18/116) gave responses different to the one expected, such as: men were fast, were old, were heavy, were mature and some answers were left blank.

Comment

From an African perspective, men had more matla/amandla than boys. To roll a heavy boulder one needed matla/amandla, to roll the boulder faster one needed matla/amandla, to roll it over a long distance one needed matla/amandla too. It was clear that boys lacked this entity (mechanics quantity). What could it be called in physics English? The known answer was clearly matla/amandla for this entity; translation into English was the problem. Some research subjects therefore said power, some said energy, some said force, some fitness and others said matla untranslated. 16% of the responses different from the ones that were expected were possibly trying to avoid the concept translation trap by using non-scientific terms which did, however, make sense. Still, the problem was to translate matla/amandla which was undifferentiated in mother tongue into English physics terms that distinctly meant separate concepts.

4.2.6 Boys could not even move the boulders because ...

When many boulders had been pushed up the mountain that could easily be rolled, larger boulders were left behind. Men would strongly push and roll these heavy ones, but it would not be easy. Boys could not even move some of these heavy ones. What was it that the boys lacked that men had, to move these boulders? The answer to this question according to the Reference group responses, was that the boys could not apply or exert sufficient force.

TABLE 4.6

Responses to the question "Boys could not even move boulders, because ..."

INS	N	No P	No E	No F	Not FIT	W	OTHER
		%	%	%	%	%	%
UNQ	20	15 (3)	5 (1)	25 (5)	-	20 (4)	35 (7)
B	4	25 (1)	50 (2)	-	25 (1)	-	-
BN	43	16 (7)	21 (9)	14 (6)	-	26 (11)	23 (10)
TAU	5	-	-	100 (5)	-	-	-
TS	6	17 (1)	34 (2)	-	17 (1)	17 (1)	17 (1)
T 3	19	26 (5)	42 (8)	10 (2)	5 (1)	-	18 (3)
T 2	19	26 (5)	68 (13)	-	6 (1)	-	-
TOTAL	116	22	35	18	4	16	21
%	100	19	30	16	3	14	18

INS :Institution
N :Number of subjects

UNQ :University of the North

No P	:No power	B	:Boitjhorisong
No E	:No energy	BN	:Bonamelo
No F	:No force	TAU	:Taung
Not FIT	:Those not fit	TS	:Teachers
W	:Weak	T3	:Tshiya College-3rd year
OTHER	:Answers different from those expected	T2	:Tshiya College-2nd year

Results

The results are shown in Table 4.6. Most of the answers given were about what the boys did not have when they could not even move the boulders. 30% (35/116) stated that the boys did not have enough energy, 19%(22/116) stated that boys lacked power, 14%(16/116) stated that the boys were weak, 16% (18/116) stated that the boys lacked force, while 3% (4/116) stated that boys were not fit. 18% (21/116) gave responses in the category that was not expected. They included reasons like: they were tired, they were young, immature, the lacked of mass, lacked weight and others were left blank.

Comment

The aim of the question was to find physics words from the subjects to determine if they could differentiate the matla/amandla concept in physics English terms at all. Being weak and being not fit are deliberately evasive answers that are not scientific but nevertheless make sense in everyday speech. The percentages were 14% (16/116) for weak, 3% (4/116) for not fit and 18% (21/116) for "OTHER" responses which were not expected. Of the 21responses, 3 indicated the lack of mass and 8 indicated the lack of, or weight smaller, than that of men as responses. 35% answered with no translation from which conceptualisation could be derived, but gave answers which made sense as translations of matla/amandla, while energy, power and force were still appearing from the subjects, providing further evidence of the difficulty in differentiating the concept. A correct answer in mother tongue is: ha ba na matla / abanamandla (they do not have matla/amandla). What don't they have in physics English? Further discussion of this phenomenon of "ha ba na matla/abanamandla/they don't have matla/amandla" is done comprehensively in Chapter Six (6.2).

Interviews

On this question of the difference between boys and men, the Pilot group on interview gave various responses of interest. Extracts of interviews with teachers Nts, Mok, Paul and Ma of this Pilot group were as given below:

Teacher Nts's extract (Appendix 19)

I :When small boys try to roll the boulders up, they cannot move, but when men move them, they manage to move and roll them. What is the difference? how are men different from boys?

Nts :Ba na le matla a fapaneng; E ka re bale ba sa le banyane (they have different matla, it seems the others are still young).

I :Ok, say it in English, my dear! (with much persuasion).

Nts : ... Force applied is different.

Teacher Mk 's extract (Appendix 9)

I :Some small boys could not even move the boulders. In terms of mechanics concepts, in what ways were the boys different from men?

Mk :I think it was in terms of the energy they have, and of course the energy that they are applying is not the same ...

I :You say energy? What kind of energy? And what else?

Mk :I can always say the power that they are using.

... ...

I :You haven't said energy and power in your language!

Mk :Energy is still matla, and power ... (long silence) nkare ke bokgoni (I can say bokgoni).

Teacher Paul's extract (Appendix 10)

I :Ok, I am coming to the 4th question: What was the difference between boys and men since boys could not even move some boulders?

Paul :Boys did not have very much, shall I say power or energy? No energy as men would do. So they would fail to exert enough to push the boulders up.

... ...

I :Alright, what is the connection between power and energy? What is power in your language?

Paul :Ke matla (is matla).

I :So you are counting four now? Energy, force, momentum and power. Ke matla kaofela (all matla)?

Paul :Hantle, ke matla kaofela (Exactly, all are matla).

Teacher Ma's extract (Appendix 17)

I :Let's go to the fourth question. Some boys could not even move some boulders. Now in terms of the mechanics concepts, what is the difference between boys and men?

Ma :The difference is their mass. For these to roll the boulders up, they need a certain amount of weight.

I :Let's come back to it, I think I like that one. You say their mass, the mass of men and boys, or the mass of boulders?

Ma :The mass of men and boys to the boulders [indicating the push with her hands].

I :Ok, why do you think a boy needs to have some mass?

Ma :For these boulders, say it is 100kg, it will need a minimum force to push it to be 1000N. So boys with small mass maybe 11kg will not apply a force of 1000N. It will be very difficult for them to meet the requirement. At least if they are three, they will meet the requirement.

I :So then in order for a man to be able to roll the boulder of 100N he must at least ...

Ma :[interruption] ... be able to exert that 100N, but to roll it upwards, it must be more!

Comment

The interview extracts illustrate difficulties the Pilot group subjects had in knowing which English term to use when translating from the word "matla". The misconception demonstrated by Ma, that the object could only move another object whose weight was less or an object could only move if acted on by a force greater than its weight has been reported (Halloun and Hestenes 1985).

4.2.7 Entity (mechanics quantity) A has to outrun B

In an ordinary race some athletes outrun others. After leaving boulders at the tcp of Thaba Bosiu, men would run downwards again to find boulders that could still be rolled up easily. Boys outran men. Boy A outran man B down to the boulders. If A outran B, what does A have that B lacks? It was correct to say A has more speed than B; momentum and kinetic energy would depend on the mass of the boy.

TABLE 4.7
Quantity A has over B for A to outrun B

INSTITU-TION	N	POWER	ENER-GY	FORCE	M	SPEED	OTHER
		%	%	%	%	%	%
UNQ	21	19 (4)	38 (8)	28 (6)	-	10 (2)	5 (1)
B	4	-	25 (1)	-	-	50 (2)	25 (1)
TAU	5	-	-	40 (2)	-	40 (2)	20 (1)
BN	44	13 (6)	37 (16)	5 (2)	-	35 (15)	11 (5)
TS	6	-	66 (4)	-	-	17 (1)	17 (1)
T 3	21	24 (5)	38 (8)	-	5 (1)	24 (5)	10 (2)
T 2	19	32 (6)	16 (3)	-	11 (2)	16 (3)	26 (5)
TOTAL %	120 100	21 18	40 33	10 8	3 3	30 25	16 13

UNQ :University of the North
B :Boitjhorisong
TAU :Taung
M :Momentum
T3 :Tshiya College - 3rd year
OTHER:Answers different from those expected
N :Number of the subjects
BN :Bonamelo
TS :Teachers
T2 :Tshiya College - 2nd year

Results

The results are presented in Table 4.7. 33% (40/120) stated that B lacks energy, 25% (30/120) stated that B lacks speed, 18% (21/120) stated that B lacks power, 8% (10/120) stated that B lacks force and 2% (3/120) said that B lacks momentum, while 13% (16/120) responded with unexpected answers such as stamina, confidence, or strength, including those answers that were left blank.

Comment

Again this was a test of the Pilot group subjects' translation of another meaning of matla/amandla. Although 25% stated that A had more speed than B, which looked obvious, it was still a kind of matla/amandla to translate from mother tongue to physics English, because there was no dispute in South African vernacular that B lacked matla/amandla as A outran him.

4.2.8 Man X arrives ten minutes before man Y at the mountain top rolling identical boulders since X has more ...

When boulders were rolled up, the boys who were quick as they ran down were now no match for the men they outran. Men were arriving at the mountain top with their boulders far ahead of the boys. They were men, they had more of this quantity than the boys. What was this quantity? Could this quantity be different from the quantity the boys had to outrun men as they were going down hill? Man X arrived 10 minutes before man Y at the top of the hill since X had more of this quantity than Y. X had more ability to generate power than Y is the correct answer. This question was not very different from the previous one where boys outran men; this time men outran boys only that they pushed some boulders uphill.

TABLE 4.8

Responses to the question "X arrives ten minutes before Y rolling the boulders since X has more ... than Y.

INSTITU-TION	N	POW-ER	ENER-GY	FORCE	M	SPEED	A	OTHER
			%	%	%	%	%	%
UNQ	22	23 (5)	50 (11)	18 (4)	-	9 (2)	-	-
B	4	75 (3)	25 (1)	-	-	-	-	-
BN	44	30 (13)	39 (17)	2 (1)	2 (1)	21 (9)	-	7 (3)
TAU	5	20 (1)	20 (1)	20 (1)	-	20 (1)	-	20 (1)
TS	4	75 (3)	-	-	-	25 (1)	-	-
T3	25	44 (11)	28 (7)	-	-	12 (3)	4 (1)	12 (3)
T2	20	25 (5)	15 (3)	5 (1)	-	-	5 (1)	20 (4)
TO %	124 100	40 32	40 32	7 6	3 2	22 18	2 2	11 9

UNQ :University of the North
N :Number of subjects
B :Boitjhorisong
BN :Bonamelo
TAU :Taung
M :Momentum
TS :Teachers
S :Speed
T3 :Tshiya College-3rd year
A :Acceleration
T2 :Tshiya College-2nd year
OTHER:Answers different from the expected ones

Results

The results are shown in Table 4.8. 33% (42/123) stated that X has more energy, 32% (40/123) stated that X has more power, 17% (22/123) said X has more speed, 5% (7/123) said X has more force, 2% (2/123) said X has more acceleration and 2% (3/123) said X has more momentum. 9% (11/123), however supplied answers like faster, stamina, gravity and blank spaces were left.

Comment

X had more matla/amandla this time going uphill where men appeared better than the boys. They used it to outclass boys that outran them down the hill. Although the answer was given that men had more power than boys, 33% (42/123) still responded with energy, 5% (7/123) with force and 2% (3/123) with momentum. Use of these terms again showed that there was a problem of interpretation caused by concept translation; energy, power, force and momentum were difficult concepts for the subjects to differentiate, one from the other.

4.2.9 Why boulder P arrives ahead of boulder Q both being identical

Boulder P got to the bottom much quicker than boulder Q, while they were identical boulders in all respects. The only difference was the path they followed. The idea was to investigate whether students noticed that the difference would be in the path.

TABLE 4.9

Identical boulders reach the bottom at different times

INS	N	V	A	Force	OBS	MA	MATH	OTHE
		%	%	%	%	%	%	%
UNQ	19	5 (1)	11 (2)	-	42 (8)	5 (1)	11 (2)	26(5)
B	4	25 (1)	-	25 (1)	0 (2)	-	-	-
BN	41	49 (20)	10 (4)	-	12 (5)	-	2 (1)	27 (11)
T2	20	40 (8)	-	5 (1)	30 (6)	5 (1)	5 (1)	15 (3)
T3	19	32 (6)	-	-	32 (6)	-	5 (1)	32 (6)
TS	8	13 (1)	13 (1)	-	38 (3)	-	-	38 (3)
TAU	5	-	20 (1)	20 (1)	-	-	-	60 (3)
TO %	119 100	39 33	8 7	3 3	30 25	2 2	5 4	32 27

INS :Institution
N :Number of subjects

UNQ :University of the North

V	:Velocity	B	:Boitjhorisong
A	:Acceleration	BN	:Bonamelo
F	:Force	T3	:Tshiya College - 3rd year
OBS	:Obstructions/Obstacles	T2	:Tshiya College - 2nd year
MA	:Matla	TS	:Teachers
MATH	:Mathata	TO	:Total
OTHER	:Answers different from those expected	%	:Percentage

Results

The results are presented in Table 4.9. 32% (37/116) stated that P had more velocity than Q, 7% (8/116) stated that P had more acceleration than Q, and 3% (3/116) stated that P had more force than Q. 26% (30/116) however, stated that Q had more obstacles or obstructions than P. 27% (31/116) stated several reasons about P like such as P had more stamina, more mass, or was heavier and others left blank.

Comment

Subjects had difficulties even just understanding the meaning of some expressions in the language that was not mother tongue; the meaning of "identical in all respects" was not conceptualised properly. This difficulty will be addressed in Chapter Five handling the Language difficulties and further in Chapter Seven.

4.2.10 Summary (Task One)

The understanding, that is, the ability to identify and the insight to distinguish the distinct entities and mechanics concepts, force, energy, momentum and power were investigated.The following observation and conclusions were made:

1 The quantity gained as boulders fell was not satisfactorily supplied by the research subjects. Although the majority of responses were correct, they contained only a single word or term where more than one term should have been given. The incorrect responses were, among others, acceleration (as noted in teacher Ma's interview), force and vigour.

2 The quantity (entity) with which boulders fell on the enemy ranged among power, force, momentum, impact and energy. Since these terms have one word in the African languages, namely matla/amandla, the suspicion is that the responses were first thought out in vernacular (as Rutherford and Nkopodi 1990 suggest), which came out to be matla/amandla, so the problem was to translate this response back into English, which is the language of instruction. Hence any of the five conceptual terms might be chosen which, although they are related in mechanics, are distinctly different from one another. The problems associated with reverse translation were picked up in this response.

3 Quantity imparted to a stationary boulder by a moving boulder on collision, confirmed the suspicion:

a. that the quantity causing or involved in motion in some direction is the said matla/amandla since some subjects did not even translate it, but leave it openly as matla

b. that the problem of reverse translation from matla/amandla into any of the terms force, power, energy, momentum and impulse correctly, indicates the difficulty the subjects have in differentiating not only the meaning of the conceptual terms, but also the words themselves.

4 The quantity involved in large amounts to kill a man as a boulder fell on him was not consistently identified since the responses ranged across all terms: power, energy, force, momentum and even included impact which is not a technical term in mechanics. While the correct responses were momentum and kinetic energy, the majority of the subjects from the written responses preferred power (25%) and force (35%), while momentum was given by 3% and kinetic energy by 10%. Most of the teachers on interview said "a large amount of force".

5 The question on the quantity that caused the boys not to be able to even move the boulders, which was their inability to exert sufficient force, had another variety of responses: not sufficient power, energy, not fit and weak .

6 The matla/amandla quantity appears to be viewed as a quantity intrinsic or carried or contained in the object or a person. Ha ba na matla/abanamandla is translated: They have no matla/amandla. All the concepts in this question also appeared to be incorrectly thought to be intrinsic such as: to have force, to have enough power or to have much energy. This problem is aggravated when some books incorrectly express the concept in a way which makes them appear intrinsic e.g. in Nelkon, M. 1975. C S E Physics (Appendix 7), or one Professor in the Reference group who responded "The boys did not have enough force". This problem may have further been exacerbated by the wording of the questionnaire, which was changed after the pilot.

7 The idea was identified that one needs to have a mass equal to or more than the mass of the object one had to move for motion to occur. The interview statement of teacher Ma, who argued that to move a boulder a boy needed mass or weight that was larger than that of the boulder confirmed the three responses which said boys needed more mass and 8 which said boys needed more weight (Watts and Zylbersztajn 1985; Grayson 1990).

From the above observations, reverse translations from vernacular to English seemed to be used in responding to the questions. Further evidence for this interpretation is presented in Chapter 5. It was seen that the subjects could not successfully differentiate the conceptual terms in that where a concept such as power was expected, energy, force and matla were almost equally given as responses since they all appear to mean matla to the subjects. Teacher Paul, who had been teaching physical science for more than twenty years at matric level, admitted in the interview that all four concepts are translated as matla (Appendix 10).

4.3 FORCES ON A BALL RISING AND FALLING

Task Two, which was labelled as Quiz Two, is given in Appendix 6. This second task in the investigation of conceptual difficulties pertained to problems that seemed to exist amongst the learners who were novices studying physics all over the world according to the work of several physics education researchers (e.g. Watts and Zylbersztajn 1981; Clement 1982; Arons 1989; Hestenes and Wells 1992; Grayson 1994b). The work of these researchers supported a constructivist theory, showing that students came to study physics with ideas already constructed about the world around them even long before the physics instruction was given to them. Examples of such constructed ideas were that:

1. motion occurs only when force is applied

2. motion is in the direction of the force applied

3. the larger the force, the faster the motion

The general suspicion that one could get from the work of the above-mentioned researchers was that African students were likely to have preconceptions similar to the ones above. This conclusion was derived from the responses of other students around the world even before analysing the local results. The preconceptions in the minds of the students in most cases will be misconceptions, and these preconceptions will be revisited in the discussion in Chapter Seven (7.3). It is necessary for such misconceptions to be known by the teachers before successfully introducing new and correct concepts to be assimilated or accommodated by the students through a process of conceptual change.

On Task 2, there was a general consensus by the whole Reference group that if the air resistance was to be neglected, there was only one force acting on the ball at all three positions 1, 2 and 3, that is, the gravitational force acting in the downward direction.

Forces on the rising ball (position 1)

TABLE 4.10

Forces on the rising ball (position 1)

INSTITUTION	N	UPWARD ALONE	GRAVITY ALONE	UPWARD = GRAVITY	UPWARD > GRAVITY
		%	%	%	%
UNQ	14	36 (5)	-	43 (6)	21 (3)
TSHIYA 3	19	26 (5)	5 (1)	11 (2)	58 (11)
TSHIYA 2	19	63 (12)	-	5 (1)	32 (6)
BOITJHORISONG	4	50 (2)	25 (1)	-	25 (1)
BONAMELO	41	83 (34)	-	7 (3)	10 (4)
SEFIKENG	19	47 (9)	-	5 (1)	47 (1)
TAUNG	5	80 (4)	-	20 (1)	-
TOTAL	121	71	2	14	34
PERCENTAGE	101	59	2	12	28

N :Number of subjects
UNQ :University of the North - QwaQwa
UPWARD ALONE: The upward force acting alone
GRAVITY ALONE: Gravitational force acting alone
UPWARD = GRAVITY: Upward force equal to Gravitational force
UPWARD > GRAVITY: Upward force larger than Gravitational force

Results

The results are summarised in Table 4.10. From this table an interesting conceptualization was noted. Four distinct answers were given by the subjects about the forces on the ball at the position labelled 1, where it had just left the hand and was on its way up. The results are as follows:

58% (71/121) of these subjects from all seven institutions, all of whom were pre-service and in-service teachers, believed that there was only an upward force acting on the ball when it was moving upwards. Note was taken of the large Bonamelo contribution to this belief (83%). 28% (34/121) indicated that there were two forces: the upward force and the force due to gravity but the upward force was the larger one. This response was particularly prevalent among Tshiya 3 subjects, 58% (11/19) of them. 12% (14/121) indicated the presence of both the upward and the gravitational forces on the ball on its way up, both forces were seen to be equal. 2% (2/121) of the subjects, one in-service teacher, and one Tshiya student, indicated that there was only one force on the ball, the weight alone, which was the correct answer. A further comment on the fact that only 2% of these teachers gave the correct answer will appear in Chapter Seven.

Comment

The following was an interpretation of the above written results that came from the responses of the subjects as to how they comprehend forces on the ascending ball at position 1:

Altogether 98% (119/121) of these present and future teachers believed in the existence of an upward force as the ball was moving upwards. Most of them were almost ready in a few months to be distributed as qualified science teachers to prepare pre-university physics students; some of them were in-service teachers who had already been teaching for a long time. This belief they had was not different from what other research subject counterparts around the world had offered as response, according to the above-mentioned researchers, showing that many learners have in their minds the constructed conceptions that there will be a force in the direction of the moving ball, even after instruction.

Only 2% (2/121), however, of all these subjects, correctly responded that there was only a force due to gravity operating on the ascending ball. This meant that only 2% of the African teachers, produced from average Colleges of Education, would teach students correctly about forces on objects rising up.

Interviews

Conversational interviews were carried out with the subjects. Although interviews were conducted for all the tasks in almost all institutions visited, only one or two typical extracts are presented below in order to indicate how interpretive conclusions were obtained. Two extracts of the interviews conducted immediately after the written responses were collected, from Boitjhorisong and Uniqwa, are given below.

Uniqwa extract (Appendix 15)

There were 14 students participating in the study at Uniqwa in this Pilot group. It is worthwhile to mention that only five of them were active in open discussions in interviews. The rest were quiet and passive. For the sake of confidentiality, the names of the subjects are withheld and they are only labelled U1, U2, U3, etc at Uniqwa, while the investigator is I. The extract follows:

I: Let us talk about forces at position 1. How many forces?

U1: There are three!

I: Somebody says three, what do other people say? (Everybody was quiet with heads down, occasionally glancing at one another).

U2: One

(Suddenly an argument started. Even those who were quiet responded openly and loudly to U2. This shouting participation was condoned, and even those who were quiet were showing life now. A strong contingent of these subjects emphasised two forces).

I: Other people say two, one person says one and another says three. When you say one, which force is it? (pointing at U2).

U2: I say one for gravitational force downwards.

I: When you say two, which forces are they?

U3: It is the force input by the hand...

I: But it has left the hand!

U3: The force of gravity and the upward force

I: (Pointing at U1)You said three, which ones?

U1: Other force will be what is an additional force.

[U1 was not sure of which force he was speaking about, the additional force was probably just in case there was another force he did not realise].

Boitjhorisong extract (Appendix 14)

Four in-service teachers of Boitjorisong were also included in the interview investigations. They were teachers who have taught in Qwa-Qwa schools for several years. They were all four over thirty (30) years of age, all very free with the investigator, knowing him from teaching together in the local Winter School of Science. 50% (2/4) of these teachers had gone through at least first year University physics besides the physics curriculum of their Colleges of Education. There was one lady and three gentlemen present in the course for physical science in this institution. Avoiding complications of asking the name of each subject who responds, the names of the subjects were replaced by B1, B2, B3 and Lele for the lady. After being instructed to neglect the air resistance on the ball just thrown up, the extract of their interview was as follows:

I: On the ball in position 1, how many forces and what are the directions?

B1: There are three forces, the one applied from the throw, there's also external unbalanced force and the last one is the force pushing the ball upwards.

I: Who is differing with you or who wants to add something?

B3: I think there are only two forces: it is the force that pushes the ball upwards, and the force of gravity that press the ball down.

(B2 interrupted with the investigator's permission and a hot argument started since B2 insisted there is only one force, namely gravity).

I: What do you think? (looking at Lele, the lady teacher who had been quiet up to this moment).

Lele: I think as long as you are throwing a ball upwards, the force is upwards from the hand.

I: So but at position 1 the hand is not there, the ball is already going on its own.

Lele: The only force will be upwards.

Teacher Ma's extract (Appendix 17)

I :Ok! Let us go back to position 1; What has happened to the force which has been facing upwards?

Ma :That force that has been used to throw the ball upwards has been balanced. It was greater than the ball's weight at position 1, at position 2 where the ball is stationary the forces are now balanced, but immediately it starts going down, the gravitational force starts exceeding that other force.

I :What would you say to someone who says that there is never an upward force on the ball once it has left the hand?

Ma :How come the ball has gone and continues upwards without the force upwards?

Comments

Interview transcripts also showed and supported the idea that was concluded from the work of international researchers that the novice physics students have ideas constructed in their minds as they come to class even long before instruction which are difficult to change by instruction (Halloun and Hestenes 1985; Osborn 1985; Redish 1994; Moji and Grayson 1995; Lynch 1996). These results agreed with the written responses where 98% seemed to harbour the incorrect force ideas mentioned earlier (4.3.2). The results further showed how difficult it was to displace these preconceptions because these subjects had all gone through physics instruction and hence the study is post-instruction.

4.3.2 Forces on the highest ball (position 2)

TABLE 4.11

Forces on the highest position of the ball (position 2)

INS	N	UP	UP=GR	UP<GR	NO FORCE	GR ONLY
		%	%	%	%	%
UNQ	14	-	36 (5)	21 (3)	7 (1)	36 (5)
T3	19	5 (1)	68 (13)	-	-	26 (5)
T2	20	-	60 (12)	5 (1)	10 (2)	25 (5)
B	4	-	50 (2)	-	-	50 (2)
BN	41	10 (4)	59 (24)	-	12 (5)	20 (8)
SEFIKENG	19	-	26 (5)	-	5 (1)	68 (13)
TAUNG	5	20 (1)	-	-	-	80 (4)
TOTAL	122	5	62	4	9	42
%	100	4	51	3	7	35

INS :Institution
N :Number of subjects
UP :Upward force
GR :Gravitational Force

UNQ :University of the North
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd year
B :Boitjhorisong
BN :Bonamelo

Results

At the highest position, the only force acting on the ball is the force of gravity, downwards. The results of the questions on forces on the ball at the highest position marked 2 (Table 4.11) showed five different kinds of responses.

51% (62/122) of the research subjects stated that there were two forces, namely the upward force and gravity, which at this position were equal. 35% (42/122) said there was only gravity operating at this position of the ball. 7% (9/122) said there was no force. 4% (5/122) indicated that the upward force was the only force that acted.

3% (4/122) stated that the upward force was still larger than gravity. Altogether 65%, of the subjects believed in an upward force while 35% thought that gravity alone acted at this highest position of the ball.

Comments

When the ball had finished ascending, it appeared instantaneously stationary before it fell down again. A large group, (58%) of these pre-service and in-service teachers, agreed that when the ball was stationary, it was in equilibrium and hence all forces on this object added up to zero. Where could the other forces be developing from to cause the ball to be in equilibrium since there was the strong "upward force" on the way up for 98% of these teachers? Could it be that some forces were decreasing while some were increasing to a point where they ultimately added up to zero at this position?

35% of the subjects however responded with gravity alone. This was the correct answer but it is a question if it was correctly obtained, particularly when compared with the 98% of the same groups that indicated the existence of the upward force on the upward going ball. Where could the upward force have disappeared to now such that it was now only gravity that was left? The last 7% were still confused about the upward force.

Interviews

As in the interview for position 1, the interview for position 2 was carried out immediately after the submission of the responses given about the ball when it was at the highest position. Sample extracts of interview transcripts follow below from two institutions, namely Uniqwa and Tshiya. Again the participating Uniqwa subjects were labelled U1, U2, U3, etc, while Tshiya subjects were labelled S1, S2, S3, etc.

It is important to add here that the general attitude of the subjects was changing, showing some tiring, in most of the institutions. The interviews became lengthy and more inquisitively prying into their science knowledge. Apparently this was not acceptable. The subjects became more and more passive to questions, especially the ladies who seemed to dislike being singled out, particularly if they were to have their voices on cassette recorders. Uniqwa subjects were not very cooperative.

Uniqwa extract is as follows (Ball at position 2) (Appendix 15)

I: On the second ball position, how many?

U1: On the second ball it seems as there are two.

I: Which one and which one?

U2: The second ball is the highest, the forces there will be the sum of all the forces acting on the ball.

I: Which forces would they be?

U2: The upward force exerted by the hand still acting but will be counteracted by the force of gravity.

I: One of the ladies, do you agree or disagree?

U3: Alright I agree.

Tshiya extract is as follows (ball at position 2) (Appendix 16)

I: Ok! Let us go to position 2. Who wants to mention forces at position 2?

S1: They are also all around the ball (indicating with the hand that there are forces pulling the ball in all directions).

I: Ok, yes (pointing at another student).

S6: An upward force is equal to the gravitational force.

I: You are speaking about two forces?

S6: Yes, for from position 1 we said upward force is greater than the gravitational force.

I: Anybody else differing with him?

S5: I don't think there are forces on that ball, but I think it is the masses...

(A lengthy debate started among the subjects themselves. A contingent convinced the whole class that the upward force(s) will equal the downward (gravitational) force because the ball is not moving but is in equilibrium (presumably from the mechanical definition of the stable equilibrium, where an object not moving is said to be in stable equilibrium).

I: So you all settle with the response that the upward force which is equal to gravitational force on the ball at that position do cancel each other and render the ball to be in stable equilibrium!

There was a general consensus and agreement on this point that the ball was stationary since it was in the said stable equilibrium.

Comments

This maximum height position was the critical position for conceptual understanding of forces. The stationary appearance of the ball was the beginning of the confusion because if indeed the ball was not moving, it is in equilibrium, according to the knowledge the students had about objects at rest, which were at equilibrium. This ball was at rest in position 2, which implied that the sum of all forces acting on the stationary object added up to zero. The students were thus confusing the fact that the velocity of the ball was zero at that instant with a situation in which a ball remained at rest and therefore would be in equilibrium (McDermott 1984; Osborne 1984; Gilbert, Watts and Osborne 1985; Sadanand and Kess 1990; Sequeira and Leite 1991 and Hestenes, Wells and Swackhammer 1992).

4.3.3 The ball moving down (position 3)

TABLE 4.12

Forces on the ball moving down (position 3)

INSTITUTION	N	GRAVITY ALONE	OTHER FORCES	GRAVITY + OTHERS	NO FORCES
		%	%	%	%
UNQ	14	43 (6)	14 (2)	29 (4)	14 (2)
TSHIYA 3	19	53 (10)	--	47 (9)	-
TSHIYA 2	20	50 (10)	10 (2)	25 (5)	15 (3)
BOITJHORISONG	4	50 (2)	--	25 (1)	25 (1)
BONAMELO	41	78 (32)	5 (2)	10 (4)	7 (3)
SEFIKENG	19	68 (13)	--	11 (2)	21 (4)
TAUNG	5	40 (2)	--	20 (1)	40 (2)
TOTAL	122	75	6	26	15
PERCENTAGE	100	62	5	21	12

N :Number of subjects UNQ :University of the North

TSHIYA 3 :Tshiya College-3rd year TSHIYA 2 :Tshiya College-2nd year

Results

As for the other positions, the only force acting on the ball was the force of gravity, downwards. The results are given in Table 4.12. This part investigated the subjects' understanding of the forces on the ball on its way down from the highest position. This position was labelled 3. It was in a way almost at the same position as the ball in position 1 but only in the opposite direction of movement, going down when the first ball was ascending.

With this task it was noticed that the longer the task took to complete, the more the deterioration of the concentration of the subjects and the less the encouragement from the investigator succeeded. Table 4.12 indicated the results of the data collected from all seven institutions.

Four distinctly different responses were obtained from the subjects. Much less confusion was apparent. It seemed clear that the subjects thought the main force wais gravity. The results were as follows:

62% (75/122) of the subjects stated the forces as gravity alone. At Bonamelo 78% (32/41) of the subjects indicated gravity alone, against 43% (6/14) of Uniqwa subjects. 21% (26/122) indicated the presence of the gravitational force along with some additional forces, such as normal forces (which did not make much sense). 47% (9/19) of Tshiya third year students gave this response.
12% (15/122) said there is no force on the ball as it falls; in particular 30% (5/15) of this group expressed their responses by not even drawing and labelling these required forces. 5% (6/122) labelled a force pointing downward as a downward force, which could still have meant the gravitational force.

Comment

It was apparently easy to accept that the falling was brought about by the gravitational force since 83% (98/122) indicated that; 21% (26/122) of this 83% however, indicated their belief that there existed some other forces. 5% (6/122) had different names for the forces: downward forces and tension acting down as other forces, but all acting downwards. This could, however, be added to 83%, so that the total number of subjects who suggested downward forces was 88%.

Comparing both the results on the rising ball and falling ball: 98% of subjects believed in the upward force with the rising ball while now 88% indicated a downward force on the descending ball. Thus the vast majority of the subjects thought that there must be a force in the direction of the motion.

Interviews

On carrying out a conversational interview about the freely falling ball at position 3, the interview at Uniqwa became suddenly quite interesting. I was for the investigator, and the university students are labelled Ux, Uz, Ul for participants. The interview extract follows:

Uniqwa extract (position 3) (Appendix 15)

I: Position 3, how many forces are there?

Ux: I am thinking about the frictional force

I: Let us neglect the frictional force

Ux: There are three: the gravitational force... (some quietness and scratching of head for some time). I wouldn't say the upward force, then others are still there...

I: Ladies, what about one of you? (pointing at one of the few ladies who would not be quick to respond unless singled out specifically)

Ul: I think the upward force is still there but since the ball is towards the earth, the gravitational force has taken over since the upward force is weak.

I: What has actually decreased that upward force?

(Silence)

I: Because you are saying the upward force is now weak, what made it weak?

(Silence)

Ux: It is because there must be increasing magnitude gravitational force ...

I: Is the gravitational force ever changing?

(Silence)

Uz: It is not changing, but all the objects are attracted with the same kind of force of gravity...

(Silence)

Uz: But the only change is in the upward force

I: What changes the upward force?

(Silence)

(There was a loud shout from one student to his neighbour: "Is it not the height?")

Uz: (Having overheard the whisper) I don't think is the upward force (shaking his head vehemently)

I: What happened to it do you think?

Uz: On the falling body? Yea it is!

I: The upward force is still there?

U: The upward force is still there

Comment

Indeed it ws the force of gravity that pulled the ball downwards, according to the subjects, but where was it when the ball was on its way up? Where was the upward force presently that was so highly regarded when the ball was on its way up? This confusion was found to be very wide spread among these subjects and was similar among many subjects in most of these institutions. Many of these subjects got the answer right that it was gravity that pulled the ball down, but there was no guarantee that they did not mention gravity because the ball was falling downwards, in the same way as they mentioned the upward force when the ball was rising. It was the upward force that caused confusion among the subjects. Even though many of them were right about gravity, they could not understand what had happened to the upward force. Also, where was gravity during the upward motion?

4.3.4 Summary (Task Two)

The conceptualization of the forces on the ball that was rising and falling reveallled numerous difficulties. 98% of the subjects indicated the presence of an upward force on the rising ball. Only two subjects indicated that it was the gravitational force alone that acted on the rising ball if the air resistance was neglected.

Most subjects confused the fact that at the maximum height where the ball had zero instantaneous velocity with its being in a state of equilibrium and thus thought the total force on the ball was zero. All subjects indicated that the dominant force was in the downward direction when the ball was coming down.

Further enlightening differences of opinion were dug out when the investigator was explaining the expected responses to the subjects. A group indicated that they expected the ball to fall directly downwards after it had left the hand if there was no other force except the gravitational force. They expected the "upward force" to sustain the "upward motion" of the ball. This misconception became conspicuous when stressed by teacher Ma in the interview when she furiously said: "How come the ball has gone upwards without the force upwards?" This illustrated the presence of the misconception that there must be a force in the direction of the motion.

4.4 SPEED, VELOCITY AND ACCELERATION

Task 3 labelled Quiz Two, is given in Appendix 6. Moving bodies can be fast, slow or stationary (moving with zero ve locity) and can be moving with constant or changing speed. Task 3 was thus used to determine if the research subjects could distinguish the concepts that had to do with motion. Table 4.13 shows the results:

TABLE 4.13

Understanding speed, velocity and acceleration

INS	N	SC	SB	SI	VC	VB	VI	AC	AB	AI
		%	%	%	%	%	%	%	%	%
UNQ	13	39 (5)	15 (2)	46 (6)	23 (3)	-	77(10	8 (1)	31(4)	62(8)
B	4	50(2)	-	50(2)	25 (1)	-	75 (3)	25 (1)	50(2)	25 (1)
T3	20	30 (6)	30 (6)	40 (8)	15 (3)	10 (2)	75(15	10(2)	-	90(18
T2	21	29(6)	33(7)	38(8)	10(2)	-	90(9)	5(1)	-	95(20
BN	42	31(13	24(10	45(19	5(2)	2(1)	93(39	7(3)	-	93(39
TO %	100 100	32 32	25 25	43 43	11 11	3 3	86 86	8 8	6 6	86 86

INS :Institution
N :Number of subjects
SC :Speed-correct answers
SB :Speed-left blank
SI :Speed-incorrect answers
VC :Velocity-correct answers
VB :Velocity-left blank

UNQ :University of the North
B :Boitjhorisong
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd
BN :Bonamelo
TO :Total
% :Percentage

VI	:Velocity-incorrect answersq	AC	:Acceleration-correct answers
AB	:Acceleration-left blank	AI	:Acceleration-incorrect answers

Results

The results are presented in Table 4.13. Results are given for the concepts speed, velocity and acceleration. 100 subjects from four institutions took part in the Pilot group investigation, the institutions being Boitjhorisong, Uniqwa, Bonamelo and two groups in Tshiya. Only the conceptual difficulties theme was handled in this chapter from this task; the language difficulty theme from this same task will be handled in the next chapter.

Speed:

The question asked for the positions where speeds of the ball were the same when the it went up and when it came down. The speeds were equal at A and G, at B and at F and C and E. It had not been shown experimentally to these African students at any stage during their education that at some positions, during the upward motion, and during the downward motion, speeds were equal, but might have been mentioned occasionally by teachers in passing that the object thrown up and coming down would have the same speed at the same height. In most cases lecturers tended to regard it as obvious.

32% (32/100) of the subjects gave correct answers, 43% (43/100) gave incorrect answers such as speeds at positions A, B and C are equal, and at positions E, F and G; while 25% (25/100) did not give any answers.

Velocity:

The question asked for the positions where velocities of the ball were the same along the ball's trajectory. Although there were positions where the speeds were equal, there would be no positions where velocities are equal. This answer might also have appeared obvious, but the result seems different:

11% (11/100) were correct in giving the answer that at no position would the velocities be the same while 3% (3/100) did not respond and 86% (86/100) gave incorrect answers such as velocities would be the same when the ball went up and be the same when the ball descends, (93% {39/42} of Bonamelo students contributed to these incorrect responses), suggesting a confusion between velocity and speed.

Acceleration:

This acceleration concept also had to do with the motion of the objects. It was expected that it was going to be obvious to the subjects that all the objects were moving with the gravitational acceleration. Perhaps a more subtle point was subjects' difficulty in realising that an object can have velocity in the opposite direction to acceleration. The results were however as follows:

8% (8/100) gave correct answers that the acceleration was the same everywhere, while 6% (6/100) gave no response. Of the remaining 86% (86/100) who gave incorrect answers, such as accelerations were equal at A and G, but different from at B and F, and at C and E, 45% (39/86) was again the Bonamelo students who responded incorrectly. That means 92% of these subjects were not really able to correctly apply the acceleration concept.

Comment

Generally there was still much to be learned about these mechanics concepts by these Pilot study group before they could be qualified to produce proper matriculants acceptable to university.

The problem here was with their training about what the concepts really meant and not their ability to understand; this was shown when the investigator explained every task after it was handled each time with the subjects. Clear and improved understanding of the concepts was usually noticed.

Summary (Task Three)

Only 32% of the Experimental group gave correct responses about the concepts of speed, 68% were having difficulties, that is, while 25% of the subjects did not respond or left the blanks, 43% gave incorrect responses such as the speed at A was equal to the speed at B. Only 11% understood the concept of velocity, 89% are having difficulties since 86% gave incorrect responses such as velocity at A was equal to velocity at G while 3% did not respond at all; Only 8% of the subjects gave satisfactory responses for acceleration while 86% responded incorrectly such as saying the acceleration at B was equal to accleration at F and different to the acceleration at A which was equal to the acceleration at G and 6% did not respond at all.

Summary (Pilot group)

This study showed that the Pilot group had numerous difficulties in understanding the concepts referring to quantities in mechanics. For the quantities gained as boulders fell, most of the subjects gave correct responses but only one term was given by most of them leading to the idea that if they gave more conceptual terms it would be giving synonyms. The same occurred in other questions, such as the one in which the quantity was needed which got imparted as one boulder collided with a stationary one. The same also happened in other questions.

The belief among these teachers in the Pilot group that there was a force upward when the ball was moving in that direction was very strong. 98% of the Pilot group had this belief. The majority of these research subjects could not distiguish speed, velocity and acceleration from one another as indicated in the results of the Task 3 (Trowbridge and McDermott 1980, 1981).

It was thus shown that a number of alternative conceptions identified by researchers in other countries were also held by African teachers, (Watts and Zylbersztajn 1981; Clement 1982; McDermott 1984; Grayson 1990; Sequeira and Leite 1991; Thijs and Van den Berg 1994). It was disturbing that in South Africa it was teachers who had these difficulties while the same were the difficulties of students that were identified in other countries. Additional problems were also identified, both the way matla/amandla was translated and how it was conceptualised (i.e. as a quantity which was intrinsic).

The existence of these incorrect conceptions about force in mechanics suggested that it might not be in physics alone but could be in the whole science curriculum, that teachers, in-service and pre-service, still must be trained well before being ready to be sent out for service. If they went out to the community schools with 98% of them propagating the existence of the upward force on the ascending ball to their students, the difficulty was with the teachers. They would continue to have this difficulty despite the multitude of books and other remedial equipment used to teach them about forces. Such problems could occur where such misconceptions were being relayed; these teachers who constituted the Pilot group might have been misinformed by their teachers who taught these misconceptions to their pupils, who presently were pre-service teachers and everybody got trapped in a vicious cycle of misconceptions about force. 98% was a very large number that showed how difficult it was for these teachers in the Pilot group. How much more difficult would it be for students? It was interesting that 2% correctly stated that there was only one force on the ball, namely, the gravitational force, both in the written responses and in the interview sessions.

Further, on the basis of other researchers' work, the difficulties were apparently the results of the ideas constructed about these science conceptions in the minds of the research subjects even before they received instruction. The difficulties were seen to persist even after instruction, proving them to be difficult to overcome. If the teachers of these subjects knew about these misconceptions that their students had, and how difficult they were to replace, as emphasised by research workers such as McDermott (1984), it would be easier for such a teacher to address the actual difficulties their students had, as suggested also by Bell and Freyberg (1985).

4.5 THE STUDENT GROUP

4.5.1 Quantity or Quantities in and on the boulders

The Student group consisted of subjects from various language and ethnic groups. Whites and Indians had English as their home language while African subjects had various African languages spoken in South Africa as their vernaculars. The correctness of their responses was compared between those having English as their home language and those having African languages as their home languages. Furthermore, the responses were compared racially, for White subjects, Indian subjects and African subjects. The subjects were all in the same class, taught by the same professor, where their learning environments were similar. Task 2 was distributed to both the Pilot and Student Groups unchanged, while the Task 1 that was given to the Student Group was abridged from ten questions that were given to the Pilot Group to only five questions which were reworded to make them clearer. The groups were both introduced in Section 3.4 under Sample selection.

The data was collected from the Student Group (which consisted of Physics 110S students who were in their first year physics, who will be continuing with engineering or majoring in physics, and also Physics 110B students who were those who would continue with life sciences) and the results are tabulated in this section in tables 4.14 through 4.23. The tabulation was classified according to the language spoken at home by the subjects. The "correctness" of the subjects' responses was determined by the responses of the Reference Group (introduced in Section 3.4 under Sample selection).

Tables 4.14, 4.16, 4.18, 4.20 and 4.22 present the number of responses given by the particular research subjects as R. In some questions more than one response was correct. Some of the subjects gave more than one response as was requested. In these tables responses were corrected and classified, regardless of the number of responses that were given from each subject. However, tables 4.15, 4.17, 4.19, 4.21 and 4.23 give the kind of responses given by each subject. Some subjects gave correct but incomplete responses, some correct and complete, some both correct and incorrect answers, some gave correct, complete and extra incorrect responses, some gave altogether incorrect responses while some left blanks.

As boulders rolled down, which quantity or quantities did they gain?

The first question in Task 1 asked for quantities which were gained by the boulders as they rolled down the mountain. There were four answers that were supplied by the Reference group, which were regarded as "correct" responses. The responses were momentum, kinetic energy, speed and velocity. Some of the subjects in the Student group gave all four conceptual terms while some gave different numbers of these terms; some gave only one term, some two and some three of these correct terms. It was however, in the light of these terms given by the Reference group that responses from the Student group were declared correct or incorrect. Generally, three of these answers were accepted as the correct and complete response, where speed and velocity were accepted as one quantity for a boulder rolling down the mountain. The expected response would then be momentum, kinetic energy and speed or velocity.

Table 4.14 shows the number of responses given by the subjects. 71 responses were given by subjects speaking African languages, 82 responses by English speakers (32 Indian subjects and 50 White subjects). (48/50) 96% of the White subjects' responses were correct, (22/32) 69% of the responses from the Indian subjects were correct while (49/71) 69% of the African subjects were correct. Among the responses of the White subjects, only two were incorrect; that is 4%. (1/50) 2% gave acceleration as an answer while the other 2% gave power as the answer. Ten responses of the Indian subjects were incorrect: (7/32) 22% gave acceleration as the answer (1/32) 3% gave force.

TABLE 4.14

Responses from students whose home language is English and those whose home language is any of the African languages to the question: As boulders rolled down, which quantity or quantities did they gain?

	R	KE	p	p, KE	s/v	acc	OTHER
ENGLISH							
Whites 110B	22	2	5	10	3	1	1
110S	28	10	-	18	-	-	-
Indians 110B	16	6	-	1	1	6	2
110S	16	5	-	9	-	1	1
AFRICAN LANGUAGES							
110B	58	21	7	3	6	11	10
110S	13	12	-	-	-	-	1
Total	153	56	12	41	10	19	15
%	100	37	8	27	7	12	10

R :Number of responses
p :Momentum
acc :acceleration
KE :Kinetic Energy
s/v :speed/velocity
OTHER : Other incorrect responses

(1/32) 3% gave power as the answer. African subjects however, gave 71 responses, 22 of which were not correct. Of these incorrect responses, (11/71) 16% were acceleration while among responses other than those mentioned, that is, the responses marked "OTHER", (2/71) 3% were force, (2/71) 3% were potential energy, while the rest, 10% (7/71) were responses such as "death of the enemy", "collision", "crops" and "destructions".

Table 4.15 shows the kind of responses given by the subjects. It indicates with N the number of subjects who participated; subjects were classified according to the language spoken at home.

TABLE 4.15

Kinds of responses on the question:"As boulders rolled down, which quantity or quantities did they gain?"

	N	Correct but Incom- plete	Correct and Com- plete	Correct and Incor- rect	Correct Complete, Incorrect	Incor- rect	Blank
ENGLISH							
Whites 110B	21	10	5	4	2	-	-
110S	27	15	11	1	-	-	-
Indians110B	14	6	-	8	-	2	-
110S	16	12	1	..	2	-	1
AFRICAN LANGUAGE							
110B	60	36	-	10	1	13	-
110S	16	12	-	4	-	-	-
Total	154	91	17	27	5	15	1
%	100	59	11	18	3	10	1

N :Number of the subjects % :Percentage

Comparison was made among 49 White subjects, 30 Indian subjects having English as their home language and 76 African subjects having seven of the African languages in South Africa as their home languages. (25/49) 51% of the White subjects gave correct but incomplete responses, (16/49) 33% gave correct and complete responses, (5/49) 10% gave both correct and incorrect responses, while (2/50) 4% gave responses that were correct and complete with extra incorrect ones; there was nobody who did not give an answer or who left a blank. Similar items were also observed among Indians and African subjects. It was however, interesting to note that 51% of the White subjects gave responses that were correct although incomplete, (16/30) 53%

of the Indian subjects gave correct but incomplete while (48/76) 63% of African subjects gave correct but incomplete responses. Furthermore (16/49) 33% of the White subjects gave correct and complete list of rcsponses, (1/30) 3% of the Indians gave correct and complete responses but no African subjects gave this kind of responses. While there was no altogether incorrect response from among White subjects, (2/30) 7% of Indian subjects gave altogether incorrect responses while (13/76) 17% of African subjects gave altogether incorrect responses. The rest of the results are presented in Table 4.15. Most incorrect responses given were acceleration, force or weight.

"When a boulder collides with a neighbouring boulder, which quantity or quantities does it impart to its neighbour?"

The second question needed a quantity imparted. From the Reference group kinetic energy and momentum were regarded as correct and complete. The results from the data collected from the Student Group appear in Tables 4.16 and 4.17.

TABLE 4.16
Responses from students to the question: "When a boulder collides with a neighbouring boulder, which quantity or quantities does it impart to its neighbour?"

	R	KE	p	p, KE	F	s/v	acc	OTHER
ENGLISH								
Whites 110B	22	9	5	4	2	1	1	-
110S	28	7	4	13	-	-	-	4
Indians110B	16	4	7	-	3	1	-	1
110S	16	8	2	5	-	-	-	1
AFRICAN LANGUAGES								
110B	58	8	22	2	7	5	-	14
110S	12	3	8	-	-	1	-	-
Total	152	39	48	24	12	8	1	20
%	100	26	31	16	8	5	1	13

R :Kinds of responses KE :Kinetic Energy

p	:momentum	F	:Force
s/v	: speed/velocity	acc	: acceleration

OTHER: Other incorrect responses

Table 4.16 shows the responses R given by the subjects of the Student Group where some gave one or more responses while others did not give any response. (42/50) 84% responses from the White and (26/32) 81% from Indian subjects both as English speakers, were correct and (43/70) 61% responses were correct from subjects whose vernaculars are African.

It was interesting to note that incorrect responses were in the following order: (8/50) 16% were from the White subjects, (6/32) 19% from the Indian subjects and (27/70) 39% from the African subjects. It was further interesting to note that those who said force was imparted, (2/50) 4% was Whites (3/32) 9% was Indian and (7/70) 10% was African subjects. There were other responses that were not correct such as force, speed, velocity, acceleration and others that were not expected such as vigour, anger and destruction. Table 4.17 shows the kind of responses the subjects in the Student group gave about this entity or quantity imparted as the boulders collide.

The observation made on correct and complete percentages on all groups, was : (18/50) 36% was from the White subjects, (7/32) 22% from the Indian subjects, and (7/76) 9% of correct and complete responses from the African subjects. (6/50) 12% of the incorrect responses came from White subjects, (4/32) 13% from the Indian subjects, and (26/76) 34% from African subjects.

TABLE 4.17

Kinds of responses on:"When a boulder collides with a neighbouring boulder, which quantity or quantities does it impart to its neighbour?"

	N	Correct but Incom-plete	Correct and com-plete	Correct and In-correct	Correct Comple te and In-correct	Incorrect	Blank
ENGLISH							
Whites 110B	23	7	5	4	2	5	-
110S	27	6	13	4	1	1	2
Indians110B	14	3	3	3	1	4	-
110S	18	7	4	3	3	-	1
AFRICAN LAN-GUAGES							
110B	60	20	3	8	1	23	5
110S	16	7	4	-	1	3	1
Total	158	50	32	22	9	36	9
%	100	32	20	14	6	23	

N :Number of subjects

"Some falling boulders can kill a man. For such a boulder to kill a man it must have a large amount of ..."

As the boulders rolled down from the mountain top, they "carried" with them some quantity or quantities, much of which would kill a man if the boulder having it fell on him. The responses that were supplied by the Reference Group consisted of three terms: Kinetic Energy, momentum and impact. However, impact was not found to be a mechanics concept taught in physics classes these days. Old physics books did use impact, but those books used in the physics classes where the present research subjects were taught, did not handle the concept "impact"; hence impact was excluded as one of the correct responses to the third question by the Student Group of this study.

TABLE 4.18

Responses from the subjects on: "Some falling boulders can kill a man. For such a boulder to kill a man it must have a large amount of ..."

	R	Kinetic Energy	momen-tum	weight	mass	Impact	Force	Other
ENGLISH								
Whites110B	22	3	4	3	5	-	2	5
110S	28	6	10	4	4	-	3	1
Indians110B	16	2	1	3	5	-	4	1
110S	16	4	1	3	3	1	1	3
AFRICAN LAN-GUAGES								
110B	58	4	5	15	15	-	6	13
110S	13	4	3	2	2	1	-	1
Total	153	25	24	30	34	2	16	24
%	100	16	16	20	22	1	11	16

R :Number of responses

Table 4.18 gives the number, R, of the responses given. (23/50) 46% of the responses from the White subjects were correct while (7/50) 14% said weight, (9/50) 18% said mass, (5/50) 10% said force, while the rest mentioned power, speed or velocity. Indian subjects, however, gave (8/32) 25% correct responses, while (16/71) 23% of African subjects gave the correct responses.

TABLE 4.19
Kinds of responses on: "Some falling boulders can kill a man. For such a boulder to kill a man it must have large amount of ..."

	N	Correct but In-complete	Correct and Comple-te	Correct and In-correct	Correct, Comple te and In - correct	Incorrect	Blank
ENGLISH							
Whites110B	21	5	1	1	1	11	2
110S	27	10	2	6	1	8	-
Indians110B	14	2	-	2	-	10	-
110S	18	3	2	1	1	10	2
AFRICAN LAN-GUAGES							
110B	60	6	1	4	2	38	9
110S	16	6	-	2	2	6	-
Total	156	32	4	16	7	83	13
%	100	21	3	10	4	53	8

N :Number of subjects

In Table 4.19, (15/48) 31% of the White subjects gave correct but incomplete responses and (3/48) 6% gave correct and complete responses; (5/32) 16% of Indian subjects gave correct but incomplete responses while no one gave correct and complete answer among Indian subjects. However, (12/76) 16% of the African subjects gave correct but incomplete answers and (1/76) 1% gave correct and complete. The incorrect responses are interesting: (19/48) 40% of White subjects were incorrect, (20/32) 63% of the Indian subjects were incorrect and (44/76) 58% of the African subjects gave incorrect responses. 30% (21/71) of African students who gave incorrect responses indicated that the quantity was supposed to have been intrinsic to the boys, while 7% (5/71) of these African students who gave incorrect responses gave a quantity that seemed intrinsic to the boulders, such as mass and weight (which some students regard as intrinsic, even though it was not).

"Some boys could not even move the boulders; in terms of mechanics concepts in what ways are boys different from men?"

When boulders were rolled back to the top of the mountain there were times when boys could not even move the boulders. Only men rolled them up. What was the difference between men and boys? The Reference Group members were not unanimous in their responses. Although most members indicated that boys could not exert or apply sufficient force on the boulders, one member said the difference was weight, another said the difference was power generation, and the third member of this group said the boys did not have enough force. However, the response that was regarded as correct was that "the boys could not exert or apply sufficient force" alone.

Table 4.20 shows the number of the responses that were given by the study subjects. Force was regarded as a correct conceptual term. (27/50) 54% of the responses from White subjects were correct, (13/32) 41% of the responses from Indian subjects were correct and (21/67) 31% of African subjects were correct. "Other" responses which were not correct were responses such as "boys were not yet strong", "the muscles of the boys were weak" or "boys have not eaten well".

TABLE 4.20

Responses from the subjects on: Some boys could not even move the boulders; in terms of mechanics concepts, in what ways are boys different from men?

	R	F	P	E	m	w	Ep	OTHER
ENGLISH								
Whites110B	22	7	7	-	2	1	1	4
110S	28	20	3	-	2	-	-	3
Indians 110B	16	7	1	3	1	2	-	2
110S	16	6	4	2	-	-	-	4
AFRICAN LANGUAGES								
110B	54	16	11	12	5	-	-	10
110S	13	5	2	3	-	-	-	3
Total	149	61	28	20	10	3	1	26
%	100	41	19	13	7	2	1	17

R :Number of responses
F :Force
P :Power
E :Energy
m :mass
w :weight
Ep :Potential Energy
OTHER :Different responses, unexpected

Table 4.21 shows the kind of responses given by the individual subjects. There were five kinds or categories of responses given; the sixth category was a very interesting one which was not expected. It was labelled "S-I" for special incorrect. It was a category that gave either weight or mass as the response, just as one of the Reference Group gave weight as a response. This seems to be the same misconception observed in section 4.2.6 among the Pilot group.

TABLE 4.21

Kinds of responses: "Some boys could not even move the boulders; in terms of mechanics concepts, in what ways are the boys different from men?"

	N	Special In-correct	Com-plete and Correct	Com-plete and In-correct	Com-plete, Correct, In-correct	Incorrect	Blank
ENGLISH							
Whites 110B	21	2	3	-	7	8	1
110S	27	-	16	6	-	5	-
Indians 110B	14	-	7	-	-	6	1
110S	18	1	8	3	-	5	1
AFRICAN LANGUAGES							
110B	60	9	21	3	-	26	1
110S	16	-	3	2	-	7	4
Total	156	12	58	14	7	57	8
%	100	8	37	9	5	37	5

The kinds of the responses were: correct, both correct and incorrect, and incorrect. There were some blank responses. (19/48) 40% of the White subjects gave the correct responses; (15/32) 47% of the Indian subjects gave the correct responses and (24/76) 32% of the African subject gave the correct responses. Altogether incorrect responses were given as follows: (13/48) 27% of the White subjects gave them, (11/32) 34% of the Indian subjects gave them and (33/76) 43% of the African subjects gave them.

Some boys could not even move the boulders : Associated Verbs

There were several responses which were given for the question of what the difference was between boys and men that boys could not even move the boulders. Several subjects gave force as a response; the interesting responses were given associated with certain verbs, as shown in Table 4.22 below.

TABLE 4.22

Boys different from men: FORCE (Associated verbs)

	APPLIED	EXERTED	HAD INSUFFICIENT	ONLY FORCE
ENGLISH				
Whites 110S	8	12	-	2
110B	3	1	-	5
Indians110S	1	5	-	2
110B	2	2	-	6
AFRICAN LANGUAGES				
110S	11	3	-	1
110B	2	1	6	8
TOTAL	27	24	6	24

List of responses: Boys different from men:

There were responses, which according to responses of the Reference group, were incorrect; however, these responses were translated that boys "abanamandla/ha ba na matla" (they don't have matla/abanamandla). Appendix 18 shows a list of most of these translations. Several of the English responses together with translations appear below preceded by the language of the subjects:

Tsonga

Boys have less energy :abafana abanawo amandla

Setswana

Men exert enough force :ba na le matla

Sepedi

Less force exerted :ba na le matla a manyane

Sesotho

have less power :ha ba na matla

Xhosa

weak relative to their mass :abanawo amanandla

Zulu

they are weak and powerless :abanamandla

they don't have enough power :abanawo amandla

not have enough energy :abanawo amandla

don't have enough power :abanawo amandla

do not have force :abanawo amandla

Force, energy, mass and power from this list appear all to be translated to matla/amandla. This list shows both the conceptual and language difficulties intertwined.

Man X arrives at the top ten minutes before man Y while rolling identical boulders up the mountain. Describe the differences between the man X and man Y in terms of as many mechanics concepts as you think relevant.

Men X and Y were rolling identical boulders up the identical routes back to the top of the mountain; man X however arrived ten minutes before man Y. What was the difference between the two men? The Reference Group was unanimous in the responses they gave except two members, of which one gave an answer that did not sound serious which said "I can go on the whole day", and the other did not give any answer. However, most of the members indicated that man X expended or generated more power than man Y. Power was thus regarded a "correct" response against which the responses of the subjects were assessed.

TABLE 4.23

Responses from the subjects on: The differences between man X and man Y fmm X arrives ten minutes before man Y in mechanics concepts.

	R	F	P	E	acc	vel	m	Other
ENGLISH								
Whites110B	22	7	6	6	-	-	-	3
110S	28	19	7	-	-	-	-	2
Indians110B	16	9	1	-	-	1	-	5
110S	16	4	1	1	1	1	-	8
AFRICAN LANGUAGES								
110B	55	17	14	4	2	3	2	13
110S	13	5	2	1	-	-	-	5
Total	150	61	31	12	3	5	2	36
%	100	40	21	8	2	3	1	24

R :Responses of the subjects
F :Force
P :Power
E :Energy
acc :acceleration
vel :velocity
m :momentum
Other :Those responses unexpected

Table 4.23 shows the conceptual term responses given by the subjects of the Student Group; (13/50) 26% of the responses from White subjects answered with power; (2/32) 6% of the answers from Indian subjects were power, and (22/76) 29% of the African subjects responses were power. However, force as a response to this question seemed to have been preferable among most subjects; (26/50) 52% of the responses from the White subjects were force, (13/32) 41% of the responses from the Indian subjects were force and (22/68) 32% of the responses from African subjects were force. The percentage of correct responses from the White, Indian and African subjects were therefore: 26, 6 and 29. Although force was regarded as an incorrect response, one member of the Reference Group responded as follows:

Man X exerted a large force (or torque) and did more work in the given time i.e. his power output was larger.

"Other" responses were that man Y was "weaker" than man X or man X was "stronger" than man Y.

Table 4.24 shows the number of the study subjects and the individual kind of responses they gave

TABLE 4.24

4.24 Kinds of responses: Difference between man X and man Y if man X arrives ten minutes before man Y in mechanics concepts

	N	Correct and Complete	Correct and Incorrect	Incorrect	Blank
ENGLISH					
Whites 110B	21	5	-	15	1
110S	27	4	3	20	-
Indians110B	14	-	-	10	4
110S	18	2	-	12	4
AFRICAN LANGUAGES					
110B	60	17	2	32	9
110S	16	5	-	7	4
Total	156	33	5	96	22
%	100	21	3	62	14

4.5.2 Forces on the ball rising and falling

Task Two was given to the Student Group unchanged from what it was when it was given to the Pilot Group in Section 4.3. It inquired about the forces on a ball thrown up, on its way upward, as it turned at the highest position and as it came down. If the air resistance was neglected as requested, the only force on the ball at each of the three positions was the downward gravitational force of attraction, according to the unanimous responses of the Reference group.

Forces on the rising ball

Several different responses were given by the subjects as shown in Table 4.25. However, it was useful to arrange the percentages of the correct responses according to language spoken at home by the subjects.

TABLE 4.25

Forces on the rising ball (Student group)

	N	up only	down only	up = down	up > down
ENGLISH					
Whites 110B	22	2	3	1	16
110S	28	-	23	-	5
Indians 110B	16	1	3	3	9
110S	16	-	8	-	8
AFRICAN LANGUAGES					
110B	60	4	17	6	32
110S	13	-	6	-	7
Total	155	7	60	10	77
%	100	5	39	6	50

Of the English speaking White subjects, (26/50) 52% gave correct responses on the rising ball, (11/32) 34% of the responses given by the English speaking Indian subjects were correct and (23/72) 32% of the subjects speaking African languages gave correct responses. Hence the percentages of correct responses for Whites, Indians and Africans were 52, 34 and 32 respectively.

Comment

There were subjects who mentioned, besides many other forces, the existence of the upward force on the ball that was rising. Of the English speaking groups, (24/50) 48% of the White subjects showed an upward force on the rising ball while (21/32) 63% of the Indian subjects showed the upward force. There were (50/73) 69% of the subjects with African languages spoken at home who showed the presence of the upward force. The presence of the upward force was thus indicated in the percentage for Whites, Indians and Africans as 48, 63 and 69.

Forces on the highest ball (position 2)

From the Reference group the correct response was that the only force on the ball at the highest position was the downward force of gravity if air resistance was considered negligible. From the results in Table 4.26: Of the English speaking groups, (31/50) 62% of the White subjects gave the response that there was only the downward force alone on the ball at this highest position, while (19/32) 59% of the Indian subjects gave the downward force only; (27/73) 37% of the subjects who have African languages as their vernaculars gave a downward force only. The percentages of correct responses for Whites, Indian and African subjects respectively were therefore: 62, 59 and 37.

TABLE 4.26

Forces on the highest position ball (position 2)

	N	Up	Down	Up = Down	Up > Down	Up < Down
ENGLISH						
Whites 110B	22	-	7	15	-	-
110S	28	-	24	4	-	-
Indians 110B	16	1	5	10	-	-
110S	16	-	14	2	-	-
AFRICAN LANGUAGES						
110B	60	1	23	32	-	4
110S	13	-	4	7	1	1
Total	155	2	77	70	1	5
%	100	1	50	45	1	3

N :Number of subjects participating

Comment

Again, it was interesting to note how the upward force was indicated by various study subjects where there were (19/50) 38% of English speaking White subjects, (13/32) 41% of Indian subjects who indicated it; while (46/73) 63% of the subjects whose vernaculars were African languages indicated the presence of the upward force. The percentage of the indication of the upward force by the groups in the Student group were for Whites, Indians and Africans: 38, 41 and 63.

Forces on the ball moving downwards (position 3)

The correct answer is that only a downwards force acts on the ball while it is moving downwards. The results are shown in Table 4.27. Most subjects were correct (according to the Reference group) on this question. Among the subjects who have English as their home language, (43/50) 86% of the White subjects and (22/32) 69% of he Indian subjects were correct, while (39/73) 53% of the subjects whose vernaculars are African languages gave the correct responses. The percentages of correct responses in the order of Whites, Indians and Africans is: 86, 69 and 53.

TABLE 4.27

Forces on the ball moving downwards

	N	Down alone	Up = Down	Up < Down
ENGLISH				
Whites 110B	**22**	**17**	**1**	**4**
110S	**28**	**26**	**-**	**2**
Indians 110B	**16**	**8**	**5**	**3**
110S	**16**	**14**	**-**	**2**
AFRICAN LANGUAGES				
110B	**60**	**32**	**7**	**21**
110S	**11**	**7**	**2**	**4**
Total	**155**	**104**	**15**	**36**
%	**100**	**67**	**10**	**23**

N :Number of subjects participating

Comment

Although most subjects gave correct responses for this question, some still have in mind the upward force operating on the ball: (7/50) 14% of the White subjects, (9/32) 28% of the Indian subjects and (34/73) 47% of African subjects. The subject percentage indicating the presence of the upward force could not be ignored; that is, for Whites, Indians and Africans being 14, 28 and 47.

As with the Pilot group, the majority of African subjects indicated that there had to be a force in the direction of motion both when the ball went up and when it came down.

Summary (Student group)

The student group responded to the questionnaires under post instruction conditions. Their performance was compared according to their languages and ethnicities. White and Indian subjects stated that their home language was English, while the African subjects had seven different home languages.

On the question of the quantity which was gained as boulders fell the order of correctness was the White, Indian and African. The "complete and correct" arrangement of the responses were also in the same order.

On the questions of quantities imparted as a falling boulder collided with a stationary boulder the percentage correctness was still in the order of Whites, Indians and Africans; the same order was also shown on the question of the quantity with which the boulder fell on a man to kill him.

On the question of the reason why the boys could not even move the boulders the correctness percentages were again in the same descending order of Whites, Indians and Africans. However, in the final question where man X pushed the boulder faster than man Y the correctness order was Africans, Whites, Indians: 29, 26 and 9.

In the second task where the forces were investigated on the ball on its way up, turning at the highest point and coming down on its own, the correctness also showed the order of Whites, Indians and Africans.

Where force was the quantity which was to be the response, the associated verbs were supplied by a good number of subjects in all the three groups. Only a number of African subjects mentioned that the boys did not "have" force; so appearing to understand force to be an intrinsic quantity. The African subjects also gave incorrect quantities as responses where "have" was used indicating that the quantities were intrinsic, such as: boys did not "have" sufficient energy, did not "have" enough power. This intrinsic factor is noted in Section 4.5.1 where the translation of the list of responses is given.

The implication was that African subjects had more problems in responding to these questions correctly, and the problems were difficult to eradicate from these African subjects even though they were taught by the same professors in the same classes with their White and Indian counterparts.

4.6 GROUPS RESPONSES COMPARED (PILOT AND STUDENT)

The summary of the correctness of the results on Task 1 and Task 2 which were performed by both the Pilot group and the Student group, is given below:

1 On the question of what boulders gained as they rolled down, where kinetic energy, momentum and speed were expected as the response "correct and complete", the percentage of correct responses given by members of the Student group who were White, Indian and African were 96, 69 and 69, respectively against 79 of the Pilot group. When observing responses grouped as "correct and complete" the percentages were 32, 3 and 0 from the Student group, while also it was a 0 from the Pilot group. The Pilot group members gave only single terms as responses except in interviews where they were persuaded to give "anything else".

2 On the question of what colliding boulders imparted, momentum and kinetic energy were expected as "correct and complete" response while mixed responses were given.The percentage of correct responses from Whites, Indian and African subjects were 84, 81 and 61 respectively against 38 of the Pilot group. However, the "correct and complete" individual responses from Whites, Indians and Africans were 36, 22 and 9 respectively against 1 (1/109) of the Pilot group.

3 On the question of a large amount of what a boulder must have when falling on a man in order that it should kill him, kinetic energy and momentum were the two quantities

expected in a response which would be "correct and complete". However, results from single responses for Whites, Indians and African subjects of the Student group were 46, 25 and 23 against 13 of the Pilot group, while the "correct and complete" percentages from Whites, Indians and Africans in the Student group were 6, 6 and 1 against 1 from the Pilot group.

4 On the question of what the difference was between men and boys that boys could not even move the boulders, force was the only term expected in the responses. The question was, however, so open that some subjects did not only give the term force alone as a response but also gave special verbs which are associated with the concept, such as "force exerted". The correct percentage from the Student group for Whites, Indians and Africans were 54, 41 and 31 respectively against 16 of the Pilot group.

5 The last question on the Task 1 asked about what X had above Y that X arrived ten minutes before Y at the top of the mountain. The only one term needed as a response was power, that is the rate of work done. In this question alone the Africans were better; from the Student group the responses for Whites, Indians and African subjects were 26, 6 and 29 against 33 of the Pilot group.

For Task 2 the data was collected on the forces the subjects thought acted on the ball when it was going up, turning round, and coming down.

6 On the question of the forces acting on the rising ball if air resistance is neglected, the percentages of correct responses, namely the gravitational force downward alone, were for the Whites, Indians and Africans from the Student group 52, 34 and 32 against 2 of the Pilot group. From Boitjhorisong Lele, and Teacher Ma, both argued that the ball could not go up if there was no upward force.

7 On the question of the forces on the ball at the highest position the correct responses from the Whites, Indians and Africans of the Student group were 62, 59 and 37 respectively as compared to 35 of the Pilot group.

8 Finally, on the question of force on the ball moving down the percentage of correct responses for Whites, Indians and Africans of the Student group 86, 69 and 53 against 62 of the Pilot group.

In general, the order of percentages of correct answers for White, Indian and African students mirrored the relative resourse devoted to the education of these ethnic groups under the previous South African government as outlined in Moji and Moji (1993). The results indicated that understanding of mechanics concepts investigated in this study by African subjects appeared to be poorer than that of other ethnic groups. The performance of the teachers in the Pilot group was very weak. This result was distressing when one remembered that the members of this Pilot group were expected to lay down the mechanics or physics foundations in the pre-tertiary institutions (before universities and before technikons). It was not surprising then when the first year African students from these teachers performed weakly, because they were coming from the teachers who taught what they did not understand. However, the results of the African subjects in the Student group were much better as compared to those of the African teachers in the Pilot group. This implied that further training of the Pilot group was necessary and could improve African teachers' mechanics understanding (although some of the teachers in the Pilot group were physics graduates who still gave incorrect responses).

4.7 SUMMARY

The conceptual difficulties of the African teachers (in Pilot group) were investigated in this chapter. The investigation was carried out on the Pilot group which consisted of teachers from the Qwa- Qwa region as outlined in the section of the sample selection (Section 3.4). The results from these African teachers in the Pilot group were compared with those of African university students and students of various ethnicities to verify if indeed these difficulties were particular to the African subjects. This comparison was achieved using the data collected from the Student group as discussed in Section 3.4. African teachers (the Pilot group) generally performed worse than African first year university students.

Generally the African subjects performed poorly in their responses. This performance was noted from the African responses in the Student group as compared to the responses of members of other ethnicities. It was further noted when the performance of the Pilot group was compared to that of the Student group.

The Pilot group together with the African members of the Student group, mostly gave a single word even when three or more terms were possible correct responses. These single conceptual term responses which were mostly given by Africans, led to the interpretation that in the African context, these conceptual terms needed as correct responses were synonymous and hence it would not be necessary to write two of them as a response to one question. Africans further therefore did not do well in giving responses which were "correct and complete" since most of their responses were incomplete as single terms responses. The synonymous aspect of the concepts is supported by the examples of the Biblical verse task where about eight terms, even though not mechanics terms, were all understood to mean matla/amandla.

The African subjects alone among the study subjects used the idea that boys did not "have" the necessary quantity, be it force, momentum, energy or power. The use of this verb led to the interpretation that these quantities were understood to be intrinsic among these African subjects. To "have" was to possess in the African context. If somebody had force, he or she could either "give" it out or keep it according to how the investigator had grown to understand to "have". However, this "have" is not correct in cases such as "having" force since force is an interaction between objects and not owned by one object. It was possible that the misconceptions of force and other quantities were revealed by the use of inappropriate verbs such as this "have". It was, however, noted that those subjects who used appropriate verbs were correct and had the necessary understanding of the concepts, verbs such as "exerted " or "applied" force, energy "dissipated" or "expended", work "done" or power "generated". Such incorrect association of verbs was noted by Gilbert, Watts and Osborne (1985) and Grayson (1990). Touger (1991), however, warned strongly against phrases such as "force acting", "force pulling" or "force on X". He indicated that they must be stated as, for example, "force exerted on X". So he warned about the careless association of the verbs.

On the question of forces on a ball or a coin thrown upwards, international researchers used school children and university students as their study subjects where 85% of the subjects (Watts and Zylbersztajn 1981), 66% of the high school students (Osborne 1985), 88% of high school students (Sadanand and Kess 1990) and 52% of university students (Sequeira and Leite 1991), indicated that force was maintaining the motion upwards. However, in the present investigation it was teachers who had taught for several years and those who were just ready to begin to teach at matric level who were the subjects; 98% of whom still believed that it was force which sustained the upward motion, vertically upwards. This was a poor performance by the teachers, and has serious implications about what they will teach.

CHAPTER FIVE

LANGUAGE DIFFICULTIES

5.1 INTRODUCTION

5.2 REFERENCE GROUP RESPONSES

5.3 MECHANICS QUANTITIES (OR ENTITIES) IN VERNACULAR

5.4 SPEED - VELOCITY - ACCELERATION

5.5 THE BIBLICAL VERSE

5.6 THE STUDENT GROUP

5.7 GROUPS COMPARED (PILOT AND STUDENT)

5.8 SUMMARY

LANGUAGE DIFFICULTIES

5.1 INTRODUCTION

Besides the conceptual difficulties that were investigated in the previous chapter, a wide variety of socio-cultural issues seemed to present further difficulties which could not be ignored. Language, standing out as the main difficulty in the cultural category, particularly when affected by numerous socio-cultural issues such as thought and mind, social attitudes, religious beliefs and other socio-cultural issues such as political affiliations (Seretlo 1973; Chomsky 1988; McKinley et al 1992; McNaught 1994), would at this stage, be investigated as a theme on its own. African students in South Africa appeared to have problems in differentiating concept terms they learned in mechanics as they interpreted them in mother tongue in order to understand their meaning. The language problem might be expected to complicate students' understanding because:

1 English is the language of instruction while it was a second or a third language for the students
2 Few physics teachers are English-speaking, so most still have problems in using English
3 Textbooks and most remedial material are not locally produced, hence analogies and examples may not be easily understood
4 African languages spoken in South Africa do not have indigenous words for many scientific terms

The results reported in this chapter are concentrated on the theme of "Language Difficulties" in learning physics by African learners.

This study was conducted in order to investigate, among other things, how in-service and pre-service African teachers in the Pilot group translated certain physics concept terms from English into their own languages. The English version of these concepts under study contained several distinct but related concept terms. The subjects of the Pilot group in the first task fluctuated around the number 110 in-service and pre-service teachers from several institutions, as introduced in Section 3.5. The first task used in this theme of language difficulties was the translation into the home languages of the subjects of the mechanical quantities (or entities) the subjects named to be involved with boulders and men, as boulders rolled down the mountain onto the enemies of Moshoeshoe. However, the task needed the vernacular terms for the English terms supplied as the answer. Again, Task 1 was the same as in the previous chapter: Moshoeshoe's wars (Appendix 4),but the vernacular responses were used to investigate the theme of language difficulties.

The second task in this theme again needed the translation of the concept terms in the task that was labelled Quiz Two (Appendix 5), being the third task in the first theme. It was in this task where the translation of the concept terms for speed, velocity and acceleration were compared with those given in vernacular.

A minor task of translation of a Bible verse from the second chapter and the nineteenth verse of the book of Ephesians (Eph.2:19), was included in the questionnaire of the task of Moshoeshoe's wars. This Bible verse task was included to show that over ten words in English which were distinct, could be seen to mean only one word in one of African languages.

Task 1, Moshoeshoe's wars questionnaire (Appendix 4) was to have the responses translated into African mother tongues. Task 2, Quiz Two (Appendix 5), needed translation of conceptual terms in the problem where the object was thrown up, went upwards on its own, turned at the highest point and fell down again. The final task administered was the minor task of translation of a Biblical verse, where a number of concept terms appeared, and the purpose of translation by the subjects was to determine how they would differentiate these conceptual terms.

The responses of the Student group were taken into consideration. This group consisted of the African students among first year students in the Physics Department of the University of Natal, Pietermaritzburg. They were taught mechanics at university level and were expected to have a clearer understanding of mechanics concepts and their respective vernacular words than the

Pilot group. The Reference group in this chapter was expected to respond with the responses similar to thse of the Chapter 4 Reference group and then agree together on the vernacular words for the responses they gave about the mechanics quantities. However, this was not found to be the case, the members of the Reference group did not agree together on the vernacular words for the English mechanics words they gave. Therefore, a separate section was devoted to the responses of this Reference group this chapter, namely Section 5.2.

5.2 REFERENCE GROUP RESPONSES

For the language theme a Reference group was used which was different from that used in the theme of the conceptual theme. The Reference group for the tasks in Chapter 5 to consist of African physicists. This group was composed of African university physics lecturers teaching in South African universities and post graduate students. A convenient occasion where most of these physicists could be found together was at the annual conference of the South African Institute of Physics (S A I P), which is held annually at a South African university. Such a conference was held at Pretoria University in July 1996. The investigator went there to collect the necessary data from the mentioned African physicists.

There were eight African physicists at the conference who belonged to several different African language groups of South Africa. The modified Task One and Task Two were given to all eight physicists and they were requested to hand the responses to the investigator before the end of the conference. Only three questionnaires were returned with responses. Of the three which were received, one from Mr J, was only answered in Zulu, no English. The responses in this Zulu one were such as the boulders were gaining "amandla and isivinini" as they rolled down. It was difficult to say which mechanics concepts were meant by these terms. One from Mr N, was only in Sesotho except for in Task 1, question 3, where he responded with "matla" "power" and the last was Mr D of the North West who responded only in English. These subjects were lecturers at their various universities and they ought to have seen the instructions on the questionnaires which indicated that both English and vernacular were needed, but they quietly gave single terms in single languages.

The three subjects were too few to be counted as the base on which to build a Reference group for Chapter 5 where two categories were expected, namely, the correctness of the responses as in Chapter four and either the appropriate vernacular terms for the concept names of the quantities observed to be involved or accurate translations of the English terms they have given as responses.

To build a substantial Reference group at least three more subjects who were authoritative in the language and in physics would be appropriate. The investigator then approached the Zulu Department of the University of Natal in Pietermaritzburg to supply the translation of the English concepts given in Chapter 4 by the Reference group so that there could be authoritative terms supplied for the concepts. The Zulu Department did not give the Zulu terms for these concepts because they were technical terms which cannot be translated by the Language Department. They referred the investigator to the Department of Education in the same University. The Education Department also did not have anybody to help with either the Zulu or any African vernacular terms for the mechanics concepts referred to in Chapter 4.

Finally Steve, a Masters student and Mike, an Honours student (not real names), both in the Physics Department in the University of Natal in Pietermaritzburg, were consulted and given the two questionnaire tasks to respond to. Further efforts to collect information about the African vernacular terms for the responses on the questionnaire were made by contacting three African Physics professors who apparently could not supply responses to the questionnaire. However, Steve, Mike and Mr J, the lecturer in Physics in Zululand University, were regarded as adequate reference for the Nguni language group, while a third person was necessary for the Sotho group responses beside the investigator and Mr N who is lecturing Physics in the University of the North. The third subject among the Sotho group became Mr Q of the Physics Department in the National University of Lesotho who agreed to be interviewed by the investigator. Mr Q was then visited and interviewed by the investigator on the 28th of November 1996. The responses of these Reference subjects are given below:

5.2.1 Responses of the vernacular Reference group

Sotho

Mr N.:

1 As boulders fell they gained: matla, lebelo
2 As boulders collided the moving one imparted: matla, lebelo
3 To kill a person boulders must fall with: matla power
4 The difference between boys and men when boys could not move boulders: matla, kelello
5 Man X arrives ten minutes before man Y since X o na le matla ho feta Y

Mr Q.:

1 As boulders fell they gained: lebelo/speed; matla a ho senya/kinetic energy
2 As boulders collided the moving one imparted: potential energy/matla; momentumo
3 To kill a person boulders must fall with: energy
4 The difference between boys and men when boys could not move boulders: matla a bona a fokola/their force output is weak or less
5 Man X arrives ten minutes before man Y: the power output of man X is more than that of man Y/mosebetsi wa X o potlakile.

Investigator:

1 As boulders fell they gained: Kinetic Energy/sefutho; momentum/ sekgahla; speed/ lebelo
2 As boulders collided the moving one imparted: Kinetic Energy, sefutho; momentum, sekgahla
3 To kill a person boulders must fall with: Kinetic energy, sefutho; momentum, sekgahla
4 The difference between boys and men when boys could not move boulders: cannot exert enough force, tshututso e a fokola
5 Man X arrives ten minutes before man Y: X generates more power, o na le matla ho feta Y

Zulu

Mr J.:

1 As boulders fell they gained: isivinini and umfutho

2 As boulders collided the moving one imparted: umfutho

3 To kill a person boulders must fall with: amandla and umfutho

4 The difference between boys and men when boys could not move boulders: amandla nesisindo zincane

5 Man X arrives ten minutes before man Y: amandla kaX ngomzuzwane maningi kunalawo kaY

Steve:

1 As boulders fell they gained: momentum, umfutho; Kinetic Energy, isivinini

2 As boulders collided the moving one imparted: umfutho, momentum

3 To kill a person boulders must fall with: lisinde, force/power

4 The difference between boys and men when boys could not move boulders: abafana abanamandla, not have enough power

5 Man X arrives ten minutes before man Y: X has greater power, exerts more force

Mike:

1 As boulders fell they gained: momentum, umfutho/amandla

2 As boulders collided the moving one imparted: umfutho/momentum

3 To kill a person boulders must fall with: umfutho omkhulu/large amount of force

4 The difference between boys and men when boys could not move boulders: abafana banamandla amancane/boys have less energy

5 Man X arrives ten minutes before man Y: X unamandla amakhulu/has more energy

5.2.2 Comment on responses

The individual responses of Task 1 from the Reference subjects were considered for both the correctness and the consistency in the vernacular meaning given:

*On the quantities gained as the boulders fell or rolled down (*Question 1*)*:

Sesotho:

All three agreed about lebelo; those who gave an English term called it speed. The second term given was matla from both Mr N and Mr Q. While Mr N did not give the English term for matla, Mr Q referred to matla as kinetic energy. However, the investigator called kinetic energy sefutho and momentum he called sekgahla.

1 Two subjects here gave two correct conceptual terms while the other gave three correct ones.

2 Matla was given by two subjects, where Mr Q called it kinetic energy, the investigator did not give matla, but called kinetic energy sefutho - they differed in that Mr Q called it matla.

Zulu:

Mr J said boulders gained isivinini and umfutho, Steve said isivinini/kinetic energy and umfutho/ momentum, while Mike said they gained umfutho or amandla meaning momentum. The three agreed that umfutho was gained which Steve and Mike referred to as momentum.

1 Two subjects gave two conceptual terms while one gave only one term where three terms were expected.

2 Two subjects referred to momentum as umfutho, one called momentum amandla.

*On the quantities imparted as a moving boulder collided with a stationary boulder (*Question 2*)*

Sesotho:

Mr N said lebelo and matla were imparted. Mr Q said matla/potential energy and momentumo while the investigator said kinetic energy/sefutho and momentum/sekgahla were imparted. Mr Q did not think there was a word in Sesotho which could accurately have the meaning of momentum, hence he prefered to leave it "Sothofied" as momentumo.

1 While lebelo was not correct from Mr N, momentum was correct from the other two subjects while Mr Q differed with the investigator in that he said potential energy in the place of kinetic energy.

2 Matla was energy for Mr Q while sefutho was energy for the investigator. They differed on the meaning of energy and of momentum - Mr Q did not want to give a Sesotho word, while the investigator called it sekgahla. Again they differed on the Sesotho meaning of these concepts.

Zulu:

While Mr J said umfutho was imparted, Steve said umfutho/momentum was imparted and Mike said umfutho/momentum was imparted. There was agreement among the Zulu speakers here: Umfutho was imparted. Umfutho was given as meaning momentum.

1 The subjects only gave one term, umfutho/momentum, kinetic energy was left out.

2 There was consensus that momentum is given by the Zulu term umfutho.

*On the quantity boulders need in order to kill a person (*Question 3*)*

(if a boulder with a large amount of this quantity fell on a person, would kill the person)

Sesotho:

Mr N said boulders should fall with matla/power (the only matla for which he gave an English word). Mr Q said boulders had to fall with energy. Although in question 1 he referred to kinetic energy as "matla a ho senya", for the energy he mentioned here in question 3 he did not attach the Sesotho word for this energy or give a translation, as if the energy he mentioned here is different from the energy in question 1. The investigator said boulders must fall with much kinetic energy/sefutho and momentum/sekgahla.

1 Power/matla was a response which is both incorrect and incomplete from Mr N. Energy, if it was kinetic, was correct but incomplete from Mr Q while the investigator gave kinetic energy/sefutho and momentum/sekgahla which was correct and complete, according to the Reference group in Chapter 4. They differed on correctness and completeness.

2 Mr N said power is matla; Mr Q did not give Sesotho word for the energy he mentioned and the investigator gave sefutho for the energy he mentioned. They were not unanimous in these vernacular terms.

Zulu:

Mr J said amandla nomfutho (amandla and mfutho) were necessary to kill. Steve said "lisinde" (meaning it must be heavy) as well as force and power while Mike said boulders needed a large amount of force/ umfutho omkhulu.

1 Mr J's answer was complete and correct if truly amandla was energy and umfutho was momentum. Steve was not correct with force and power while Mike was also not correct with large amount of force.

2 Steve referred heaviness of "lisinde" to force and power while Mike refers to force as mfutho. Although they agreed about force as the response (which was incorrect), they disagreed on the Zulu term for force.

*On the difference between boys and men when boys could not move the boulders (*Question 4*)*:

Sesotho:

Mr N said matla and kelello was the difference, Mr Q said matla a bona a fokola/ their force output was less while the investigator said tshututso ya bona e a fokola/ they cannot exert enough force.

1 From Mr N if matla was power as he mentioned in question 3, and kelello was sense as the investigator knew it, the responses were incorrect. From Mr Q force output was correct and from the investigator exerting force was correct. Two were correct and one was not.

2 While Mr N mentioned matla to mean power in question 3, Mr Q mentioned matla to be energy in question 1. Mr Q in this question said "matla a bona a fokola/ their force output was less while the investigator spoke about force as tshusumetso.They did not agree on the meaning of matla. Mr Q now indicated matla to mean force, unlike in question 1 where he said matla meant energy.

Zulu:

Mr J said amandla nesisindo zincane (amandla and isisindo were small). Steve said abafana abanamandla/boys did not have enough power while Mike said abafana banamandla amancane/ boys had less energy.

1 While Mr J said amandla and isisindo (which meant heaviness) was the difference, Steve spoke about power being the difference between the boys and the men in moving the boulders and Mike said energy. They all three differed and were incorrect. Force was the correct response.

2 Steve linked amandla to power and Mike linked amandla to energy but did not qualify which kind of energy. Mr J also mentioned amandla but gave no English word. Amandla was therefore agreed upon as the correct response while its English counterparts were different from different interviewees. There was no consensus about the English word for amandla.

*On the difference between man X and man Y when man X arrives ten minutes before man Y (*Question 5*):*

Sesotho:

Mr N said man X had more matla than Y, Mr Q said the power output fro.n X was more/mosebetsi wa X o potlakile (work was fast) and the investigator said X generated more power/ X o na le matla a fetang a Y.

1 Since Mr N said matla was power in question 3, he probably regarded matla as power in this question also. Mr Q spoke about power output while the investigator also said X generated power. All three were correct and complete responses.

2 Mr N and the investigator agreed on matla being power, which was a term for the rate at which work was done. Mr Q stated that work was done rapidly/mosebetsi o potlakile. They all agreed on the word for power.

Zulu:

Mr J said amandla kaX ngomzuzwane maningi (amandla of X in a second was more). Steve said X had greater power and gave no Zulu word while Mike said X unamandla amakhulu/ man X had more energy.

1 Mr J and Mike agreed on amandla where Steve did not give a Zulu term but where his response of power was correct. The English term for amandla from Mike, i.e. energy, was incorrect.

2 There was no agreement between Steve and Mike whether amandla was power or energy.

Matla/amandla was used for most of the mechanics quantities involved. However, there was no consensus as to which particular concept it referred to among the various English mechanics concepts. In question 1 Mr Q said matla is energy while Mike said amandla is momentum, in question 4 Steve said amandla was power while Mr Q referred to matla as force. However Steve was in agreement with the investigator in question 5 who said power for matla as opposed to Mike who said energy for amandla.

Extract from the interview with Steve and Mike (Appendix 24):

Steve: What I understand about amandla? If you have more amandla it means you have more power.

I: So amandla you will say is power? How do you feel Mike?

Mike: Yes, that's what came to my mind as well, amandla means power and energy.

5.2.3 Summary

There was therefore no consensus as to which concept could be referred to as matla/amandla. Apparently several concepts were seen to be matla/amandla but were not consistently differentiated one from the other.

The expectation was that the responses would be similar to those of the Reference group of Chapter 4 which are shown in Section 4.2. They were in some cases not the same. The African physicists mostly gave single terms for responses, such as giving only momentum as a quantity which was gained when boulders rolled down the mountain, where otherwise three or four terms, speed, velocity, momentum and kinetic energy were expected. This tendency to give only a single response was also noticed among the African learners who were the subjects of this study. On a few occasions African physicists qualified the energy they gave as kinetic, but in most cases they mentioned only energy unqualified, unlike the Reference group in Chapter 4 who were explicit in mentioning "kinetic energy".

To build up a reference memorandum, a further consultation was done on a Sesotho-English dictionary by Casalis (1981). Table 5.1, summarize the results as follows:

TABLE 5.1

Mechanics terms from Sesotho speaking physicists

	Investigator	Mr Q	Mr N	Dictionary
Energy	sefutho	matla	matla	matla
Momentum	sekgahla	momentumo	matla	does not appear
Force	tshututso theselo, kgulo	matla	matla	matla, sekgahla
Power	matla	mosebetsi o potlakile	matla	matla

For the Zulu language the Reference memorandum was put together in a similar way. The last authority consulted about the meaning of the conceptual terms was the combined English-Zulu Zulu-English Dictionary by Doke et al (1990). Table 5.2 gives the English words which the two post-graduate students mentioned earlier gave for amandla, and the indication as to how interchangable is the use of amandla among the mechanics concepts which are otherwise explicit in English.

TABLE 5.2

English word for amandla from Zulu speaking physicists

	Steve	Mike	Dictionary
Energy	umdlandla	amandla	amandla umdlandla
Momentum	umfutho	umdlandla	umfutho
Force	No Zulu word	umfutho	amandla
Power	amandla	amandla	amandla umdlandla

Mr J did not give English words for the Zulu terms he gave.

With the aid of the responses gathered in these tables, the investigator put together the Reference responses which were the most likely to be the right ones since the African physicists did not always give the correct English term.

It was from these results that it was concluded that the terms in African vernaculars did not have consistent English counterparts with the same meaning in mechanics. This absence of consistency in conceptual meaning of the quantities studied across the language gap would be likely to affect the learning and understanding of such concepts adversely. Because of this inconsistency among African Physics authorities, Science teachers and dictionaries about which African words to identify in order to differentiate one concept from another accurately , the investigator failed to put together a proper Reference memorandum in which "correct" African terms are contained. It was thus not possible to assess whether the responses in African languages were correct or incorrect from the Pilot group and the Student group.

5.3 MECHANICS QUANTITIES IN VERNACULAR

5.3.1 As boulders rolled down, they gained ... (mechanics quantity in vernacular)

When the enemy was approaching, Moshoeshoe would collect everybody up onto Thaba Bosiu together with all the flocks and herds. He would allow the forces of the enemy to climb a single climbable path quite a distance up the mountain and then unleash the boulders down the path!

TABLE 5.3

As boulders rolled down, they gained ... in vernacular

INS	N	SLJ	MMA	EMA	S	M	E	V	OTH
		%	%	%	%	%	%	%	%
B	4	25 (1)	50 (2)	-	-	25 (1)	-	-	-
UNQ 1	13	15 (2)	8 (1)	23 (3)	8 (1)	15 (2)	15 (2)	-	15 (2)
T 2	20	5 (1)	20 (4)	-	20 (4)	20 (4)	20 (4)	-	15 (3)
T 3	20	5 (1)	40 (8)	35 (7)	-	5 (1)	5 (1)	-	10 (2)
BN	43	5 (2)	2 (1)	2 (1)	26 (11)	12 (5)	19 (8)	2 (1)	33 (14)
UNQ 2	6	-	-	-	17 (1)	33 (2)	33 (2)	-	17 (1)
TOTAL	106	7	16	11	17	15	17	1	22
%	100	6	15	10	16	13	16	1	20

INS :Institution
N :Number of the subjects
SLJ :Speed/lebelo/jubane
MMA :Momentum/matla/amandla
EMA :Energy/matla/amandla
S :Speed
M :Momentum
OTH :Other responses

UNQ :University of the North
B :Boitjhorisong
BN :Bonamelo
T3 :Tshiya College-3rd year
T2 :Tshiya College-2ndyear
V :Velocity

Written Results

The results are shown in Table 5.3. The questionnaire had an instruction that the given answers should also be translated into the vernacular of the subjects. The four correct answers were: speed, velocity, momentum and kinetic energy. There were four sets of responses from the subjects.

1. The first set consisted of subjects who gave incorrect answers. Most of these subjects gave wrong answers in English which were nevertheless interesting answers such as force, power and acceleration. There were 22 out of 106 subjects in this answer set and they constituted 20% of all the five institutions that were the venues of this project. Of all these institutions, Bonamelo had 33% (14/33) in this answer set; most other institutions had the average of 15% of their subjects in this answer set.

2. The second set consisted of those who did not give the vernacular terms as requested in the instructions but kept to English alone in their responses with the expected answers. There were 50 out of all 106 that fall in this category making up 47%.

3. The third and fourth sets were those who tried, or followed the translation instruction on any of the answers: 6% (7/106) translated speed as lebelo/jubane depending on whether they were Sotho or Nguni while 15% (16/106) translated momentum as matla/amandla.

4. The last set of these subjects: 10% (11/106) translated energy (kinetic) as matla/amandla in their responses.

In all the responses of these subjects 34 out of 106 gave the vernacular words as required; they constituted 33%. 50 out of 106 did not give vernacular terms but gave correct English terms; they constituted 47%. The last 22 of these subjects out of the 106 were those that did not get the right answers and did not give a vernacular version of their answers; they constitute the other 20%.

Comment

There are three or more ways in which these responses can be interpretea. the first is to appreciate the 33% of the subjects who gave the vernacular terms according to instructions. The second is to investigate the reason(s) why 46% of these subjects did not follow the instruction to supply the vernacular, while the third could be to look into the wrong responses supplied by the 20% of these subjects (as shown in Table 4.1).

7 of all 106 (6%) subjects translated speed as lebelo/jubane while no one translated velocity at all. It was, likely however, that it was because of these undifferentiated terms in mother tongue of these subjects that they translated this entity that was being gained being speed, as lebelo/jubane, and ignored velocity since they both appeared the same to the learners, namely, as a change of position with time. It was , however, worthwhile to note that, of the subjects who responded with the wrong answers, 12 out of all the 106 (11%) research subjects responded that the entity that would be gained as the boulders fell is acceleration. According to the interpretation of the investigator, these students (learners) also regarded acceleration as similar to both speed and velocity since all three were viewed as the change of position with time. Of these subjects who gave incorrect responses, which constituted 21% (22/106), 14 were from Bonamelo which was actually 33% of the Bonamelo subjects.

The second set of subjects either did not notice the instruction that they should give the vernacular translation terms, or they ignored the instruction, possibly because of the problem of undifferentiated concept terms in African vernaculars. 47% was a considerable number to have not followed the instructions.

12 subjects out of 106 (11%), indicated that energy (kinetic) was gained as the boulders fell, all translating this energy as matla/amandla, while 19 of these subjects (about 17%), gave kinetic energy as the entity that was being gained as boulders fell, but did not give the vernacular terms for it.

Interviews

The complete interview transcript of Teacher Mk appears in Appendix 9. The extract below shows how he responded to the question concerning the quantity gained as the boulders rolled down the mountain.

Teacher Mk's extract (Appendix 9)

I :Ok, you say potential energy as well. Is there anything else or they are the only two? Are you satisfied with potential energy and momentum?

Mk :Yea, I am satisfied.

I :What would you call them in your own language? Remember we must also know them in our own language.

Mk : (He frowned a long time) Momentum in my own language? (He shook his head).

I :Is there no word for that? (I asked because it him took a long time to respond further).

Mk :Yea, I think so, not unless I explain it.

Teacher Ma's extract (Appendix 17)

I :Can you express in your language? What can you call momentum and acceleration in your language? (Ka puo ya heno/In your language).

Ma :Ka puo ya ka (In my language?) Di gainile acceleration-lebelo le eketsehile (They gained acceleration - lebelo has been increased).

I :Ok, momentum ona ke eng (what then is momentum?)?

Ma :Momentum (frowning!) nkare mass le velocity di a eketseha (I can say mass and velocity increase).

I :Ke batla o hlalosetse motho eo e leng ngoana wa matric, o se ke wa hlalosetsa nna (I want you to explain to a matric child and not me).

Ma: :Nkare (I can say)... (long quietness).

Comments

These two teachers failed to give vernacular words for momentum. The subjects who did not give the translation in the Pilot group seemed to be reluctant to commit themselves, since such concepts were apparently not a familiar part of their own mother tongue that they may be given names.

5.3.2 Boulders fell down on the enemy with ... (the quantity in vernacular)

Boulders needed to be "strong" as they fell on the enemy in order to kill them. There is therefore an entity they must have when they fall on the enemy. The question needed this (mechanics quantity) entity both in English and in the vernacular from 117 subjects.
Table 5.4 appears below:

TABLE 5.4

Boulders fell on the enemy with... - vernacular

INS	N	PMA	EMA	FMA	IMA	SLJ	P	F	S	M	OTHE
		%	%	%	%	%	%	%	%	%	%
UNQ	20	15 (3)	-	20 (4)	-	5 (1)	10 (2)	5 (1)	25 (5)	-	20 (4)
B	4	-	-	25 (1)	-	25 (1)	-	25 (1)	-	-	25 (1)
BN	42	-	-	2 (1)	7 (3)		19 (8)	38 (16)	14 (6)	5 (2)	14 (6)
TAU	5	-	-	-	-	20 (1)	-	60 (3)	-	-	20 (1)
TS	6	17 (1)	-	17 (1)	17 (1)	17 (1)	-	-	-	17 (1)	17 (1)
T3	19	21 (4)	5 (1)	26 (5)	5 (1)	16 (3)	-	5 (1)	5 (1)	-	16 (3)
T2	21	5 (1)	5 (1)	19 (4)	5 (1)	11 (2)	-	24 (5)	19 (4)	-	14 (3)
TO %	117 100	9 8	2 2	16 14	6 5	9 8	10 8	27 23	16 13	3 3	19 16

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
EMA :Energy/matla/amandla
FMA :Force/matla/amandla
IMA :Impact/matla/amandla
SLJ :Speed/lebelo/jubane
P :Power
E :Energy
M :Momentum

UNQ:University of the North
OTHE:Other responses
B :Boitjhorisong
BN :Bonamelo
TAU:Taung
TS :Teachers
T3 :Tshiya College - 3rd year
T2 :Tshiya College - 2nd year
TO :Total
% :Percentage

Written Results

Table 5.4 was tabulated from the responses of the subjects. 36% (42/117) responded with both English and vernacular. Several concept terms were given as the entity with which boulders fell down on the enemy. They were power, energy, force, impact and speed, all translated to, or from vernacular as matla/amandla (in Sotho/Nguni). 48% (56/117) of the subjects did not give any vernacular word for the concept terms they wrote. They gave only English answers. 16% (19/117) gave answers that were different from those that were expected. Some of these unexpected terms were translated:

> strong, which was not expected because the instruction had indicated that it was not to be used although it was translated as matla/amandla; effort, being vague and unscientific, was also not expected, but it was given and translated as matla/amandla.

15% of the subjects did not answer the questions.

Comment

36% (42/117) of these subjects responded with translations and gave the terms power, energy, force and impact as matla/amandla. It was interesting that the unexpected terms, strong and effort were also translated as matla/amandla. 48% (56/117) did not give the vernacular words either because they did not notice the instruction that they should supply it, they did not know it or maybe they did not want to run into a repeated matla/amandla translation, if they previously had given matla/amandla as translation. There was a probability that they saw that the wanted word was matla/amandla for all the terms that were so explicitly differentiated in English; it was embarrassing to give one word on translation when one knew that the terms did not have one meaning. In short, these related mechanics concepts of power, energy, force, impact, momentum and impulse seemed to be translatable only to a single term, namely, matla or amandla depending on the vernacular group, by the Pilot group, although other vernacular terms were given by the Reference group. There were a few subjects who used other terms inconsistently to mean any of these above-mentioned mechanics terms: some said force was umfutho in Zulu, while some said umfutho was momentum. Such translations appear under "other".

5.3.3 Each boulder colliding with its neighbour imparts ... to it (quantity in vernacular)

As a boulder rolled down the slope, it collided with those boulders that were left on the way and never reached the top of of the mountain. These rolling boulders then imparted some entity to these stationary boulders and they all started rolling down. The entities in English are momentum and kinetic energy. What are they in mother tongue? Table 5.5 gives the results.

TABLE 5.5

Each boulder colliding with its neighbour imparts ... to it (in vernacular)

INS	N	PMA	EMA	FMA	MMA	P	E	F	M	MA	OTH
		%	%	%	%	%	%	%	%	%	%
UNQ	20	-	10 (2)	-	-	5 (1)	20 (4)	-	15 (3)	10 (2)	40 (8)
B	4	-	50(2)	-	50(2)	-	-	-	-	-	-
BN	43	2 (1)	-	-	-	5 (2)	2 (1)	16 (7)	19 (8)	-	56 (24)
TAU	5	-	-	20 (1)	-	20 (1)	40 (2)	-	-	-	20 (1)
TS	6	17 (1)	-	-	-	..	33 (2)	17 (1)	33 (2)	-	-
T3	19	-	21 (4)	-	10 (2)	-	5 (1)	5 (1)	21 (4)	-	37 (7)
T2	19	-	5 (1)	11 (2)	5 (1)	5 (1)	5 (1)	11 (2)	21 (4)	-	37 (7)
TO	116	2	9	3	5	5	11	11	21	2	47
%	100	2	8	3	4	4	9	9	18	2	40

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
EMA :Energy/matla/amandla
FMA :Force/matla/amandla
MMA :Momentum/matla/amandla

B :Boitjhorisong
BN :Bonamelo
TAU :Taung
TS :Teachers
T3 :Tshiya College-3rd year

P	:Power	T2	:Tshiya College-2nd year
E	:Energy	TO	:Total
F	:Force	%	:Percentage
M	:Momentum	MA	:Matla
OTH	:Other response		
UNQ	:University of the North- QwaQwa		

Results

Table 5.5 was compiled from the results. 39% (12% + 27%) responded with energy and momentum, 8% said energy is matla/amandla while 4% momentum is matla/amandla which were the correct terms. Matla/amandla was also further given as the mother tongue term for power and force, which are terms that are not correct. 17% (19/116) gave vernacular versions of these terms, while 2% (2/116) answered only with matla and did not give the English word for the answer.

42% (50/116) of the subjects did not translate the terms they gave as answers. 40% (47/116), however, gave answers with other responses different from the correct ones, such as effort, strong, movement and push. Their dominant translation was matla/amandla. Other subjects did not answer the questions and their number was counted with the 41% of the answers that were not expected.

Comment

16% (19/116) indicated that matla/amandla was imparted from the rolling boulder to the stationary boulders and set them to roll along. Translation from vernacular to English differed across power, energy, force and momentum, but they were all translated from matla/amandla. Apparently matla/amandla was a sure answer among these subjects, while English terms were difficult to decide about. This hypothesis was further supported by the 2% (2/116) that left "matla" untranslated.

41% (47/116) either did not see the instruction that translation or expression in vernacular was needed, or were shy to make redundant repetition of matla/amandla, and left the answer untranslated.

Matla was left untranslated by 2%, possibly indicating that there was a problem with the reverse translation. First the entity or this mechanical quantity was understood in mother tongue to be matla, then this matla was to be translated into English where the difficulty showed up since there were several conceptual terms from among which the correct one should be chosen.

5.3.4 To kill a man a boulder must fall on him with much ... (the quantity in vernacular)

In those Moshoeshoe's wars the aim was to kill the enemy. Boulders needed to fall hard on the enemy with much of some entity to accomplish the purpose. What entity was it in English and in vernacular that boulders had to have? Momentum and kinetic energy are the correct answers. The results are shown in Table 5.6 :

TABLE 5.6

To kill a man, a boulder must fall on him with much... vernacular

INS	N	PMA	SLJ	FMA	IMU	P	E	F	M	S	OTHE
		%	%	%	%	%	%	%	%	%	%
UNQ	20	10 (2)	10 (2)	15 (3)	-	10 (2)	15 (3)	20 (4)	10 (2)	5 (1)	5 (1)
B	4	50 (2)	-	25 (1)	25 (1)	-	-	-	-	-	-
BN	43	2 (1)	2 (1)	-	-	23 (10)	19 (8)	21 (9)	-	14 (6)	19 (8)
TAU	5	-	20 (1)	20 (1)	-	20 (1)	-	40 (2)	-	-	-
TS	6	-	-	17 (1)	17 (1)	-	-	50 (3)	17 (1)	-	-
T3	19	16 (3)	16 (3)	32 (6)	5 (1)	5 (1)	5 (1)	5 (1)	-	5 (1)	11 (2)
T2	19	5 (1)	-	16 (3)	5 (1)	32 (6)	-	32 (6)	-	5 (1)	5 (1)
TO %	116 100	9 8	7 6	15 13	4 3	20 17	12 10	25 21	3 2	9 8	12 10

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
SLJ :Speed/lebelo/jubane
FMA :Force/matla/amandla
IMU :Impact/matla/umfutho
P :Power
E :Energy
F :Force
M :Momentum
S :Speed
OTHE :Other responses
UNQ :University of the North-QwaQwa

B :Boitjhorisong
BN :Bonamelo
TAU :Taung
TS :Teachers
T3 :Tshiya College-3rd year
T2 :Tshiya College-2nd year
TO :Total

Results

Table 5.6 above shows the written results. 90% (104/116) of the subjects responded with one of the following results, namely, power, energy, force, momentum, impact and speed. Of this 90%, 24% (28/116) translated power, energy, force and impact as matla/amandla, 6% (7/116) gave speed as an answer and translated it as lebelo/jubane. The other 60% (69/116) did not translate the terms they gave as answers which were power, energy, force, impact and speed.

10% (12/116) gave other responses different from those mechanics terms, which were effort, action, work and pressure, some of which were translated as matla/amandla, some were left blank.

Comments

Power, energy, force and impact were all translated as matla/amandla depending on the vernacular. As in previous responses, matla/amandla appears to be the entity to identify. Hence the translation was concluded to have been from vernacular to English. 24% (28/116) translated from the certain vernacular term to uncertain English terms. 58% (69/116), however, did not translate the terms they gave as responses, namely, power, energy, force, momentum and speed.

5.3.5 Men rolled the boulders up faster than boys, because ...

In peace times the game the males played in Moshoeshoe's community was to roll the boulders up the slope. Those males who had more matla/amandla than the others rolled boulders faster than those who did not have enough matla/amandla in them. The question is asked in English why men rolled boulders faster than boys. The answer that would come from the Moshoeshoe community would be: "Ha ba na matla" in Sesotho, "Abanamandla" in Ngunis, meaning, "They don't have matla/amandla"; men have more matla/amandla than boys. The problem is to translate the idea into English.

Results

The written results are shown in Table 5.7:

TABLE 5.7
Men rolled the boulders faster than boys, because ... (vernacular)

INS	N	PMA	EMA	FMA	FSM	P	E	F	M	OTHE
	%	%	%	%	%	%	%	%	%	%
UNQ	20	-	20 (4)	10 (2)	5 (1)	10 (2)	20 (4)	10 (2)	10 (2)	15 (3)
B	4	50 (2)	-	25 (1)	25 (1)	-	-	-	-	-
BN	43	5 (2)	-	-	5 (2)	35 (15)	19 (8)	14 (6)	5 (2)	19 (8)
TAU	5	-	40 (2)	-	-	40 (2)	-	-	-	20 (1)
TS	6	33 (2)	17 (1)	-	-	-	17 (1)	-	-	33 (2)
T3	19	26 (5)	26 (5)	16 (3)	11 (2)	-	5 (1)	-	-	16 (3)
T2	19	16 (3)	16 (3)	-	5 (1)	11 (2)	21 (4)	21 (4)	5 (1)	5 (1)
TO %	116 100	14 12	15 13	6 5	7 6	21 18	18 16	12 10	5 4	18 16

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
EMA :Energy/matla/amandla
FMA :force/matla/amandla

B :Boitjhorisong
BN :Bonamelo
TAU :Taung
TS :Teachers

FSM	:Fit/strong/matla	T3	: Tshiya College-3rd year
P	:Power	T2	: Tshiya College- 2nd year
E	:Energy	TO	:Total
F	:Force	%	:Percentage
M	:Momentum		
OTHE	:Other responses		
UNQ	:University of the North-QwaQwa		

36% (42/116) gave translations of the terms power, energy, force, strong and fit as matla/amandla. 48% (56/116) gave responses in English alone, with no translations, while 3% (4/116) gave answers as matla with no English term. 16% (18/116) gave words like mature, fast, old, heavy and strong with diverse translations.

Comments

The results indicate from the 36% (42/116) that matla/amandla is the answer the subjects accepted to be correct. 3% (4/116) confirmed the idea by giving matla alone with no English term as an answer. However, 48% (56/116) may have felt shy to give matla/amandla over and over as the answer and only gave an English answer.

5.3.6 Boys could not even move the boulders because ... (vernacular)

When only heavy boulders were left, boys could not even move them in the game to roll them up the hill. Surely there must be something these boys lacked which men had in order to be able to roll these heavy boulders up. These boulders were separating men from boys.

Results

Table 5.8 shows the results: 32% (37/116) of the subjects responded in English and vernacular with one of the following responses: boys had no power, no energy, no force, not fit and they were weak. The translation was that " Ba hloka matla", "Abanamandla".

TABLE 5.8

Boys could not even move the boulders because ... (vernacular)

INS	N	NP M	NE M	NF M	WF	NP	NE	NF	W	OT HE
		%	%	%	%	%	%	%	%	%
UNQ	20	-	5 (1)	10 (2)	20 (4)	15 (3)	-	15 (3)	-	35 (7)
B	4	25 (1)	50 (2)	-	25 (1)	..	-	-	-	-
BN	43	2 (1)	2 (1)	-	5 (2)	14 (6)	19 (8)	14 (6)	21 (9)	23 (10)
TAU	5	-	-	60 (3)	-	..	-	40 (2)	-	-
TS	6	17 (1)	17 (1)	-	17 (1)	..	17 (1)		17 (1)	17 (1)
T3	19	26 (5)	37 (7)	5 (1)	5 (1)	..	5 (1)	5 (1)	-	18 (3)
T2	19	18 (3)	42 (8)	-	5 (1)	11 (2)	26 (5)	-	-	-
TO %	116 100	11 10	20 17	6 5	10 9	11 10	15 13	12 10	10 9	21 18

INS	:Institution	BN	:Bonamelo
N	:Number of subjects	TAU	:Taung
NPM	:No power/matla/amandla	TS	:Teachers
NEM	:No energy/matla/amandla	T3	:Tshiya College-3rd year
NFM	:No force/matla/amandla	T2	:Tshiya College-2nd year
WF	:Weak/not fit	TO	:Total
NP	:No power	%	:Percentage
NE	:No energy	W	:Weak
OTHE	:Other responses		
UNQ	:University of the North-QwaQwa	B	:Boitjhorisong

50% (58/116) of the subjects responded in English only indicating that boys lacked power, lacked energy, lacked force, did less work and they were weak. 18% (21/116) responded with answers different from those expected such as the boys were tired, were young and were immature, given with some translations.

Comments

32% (37/116) responded with expected answers and translations that boys lacked matla/amandla. While the subjects were sure that the boys lacked matla/amandla, the trouble was to translate matla/amandla to the appropriate English term. 50% (58/116) were non-committal by not giving vernacular terms, while 18% (21/116) gave some apparently random translations such as they are weak : "ba fokola", not fit: "abakaqini" and others translations of the same order. However, in the everyday conversation, boys do not have matla/amandla. "Ba hloka matla", "Badinga amandla", "They lack matla/amandla" or "ha ba na matla/abanamandla".

Interviews

The interviews showed the confusion about the vernacular terms given as terms for the English responses provided. Teacher Paul was the best of all the subjects. He was very open about the matla issue on all the conceptual terms in question. Teacher Mk battled in search of a word which will fit where people ordinarily use "matla".

Teacher Paul's extract (Appendix 10)

I : Ok, I am coming to the 4th question. What was the difference between boys and men since boys could not even move some boulders?

Paul :Boys did not have much ..., shall I call it power or energy? no energy as men would do: so they would fail to exert enough force to push the boulders up.

I :At first you said energy or power, now you say force....alright what is the connection between energy and power. What is power in your language?

Paul :Ke matla.

I :So you are counting four? Energy, force, momentum and power! Ke matla kaofela (all matla's)?

Paul :Hantle! Ke matla kaofela (exactly, all matla's).

Teacher Mk's extract (Appendix 9)

I :We go to the fourth question. Some boys could not even move boulders. In terms of mechanics concepts, in what ways were the boys different from men?

Mk :I think it was in terms of the energy that they have, and of course the force that they are applying is not the same as ...

I :You said energy? What kind of energy? And anything else?

Mk :I can also say the power that they are using.

I :You said energy and power?

Mk :Yea, I want to combine the two

I :You haven't said energy and power in your language!

Mk :Energy e ntse e le matla, power [long thinking], bokgoni (energy, matla; power, bokgoni).

Comment

Teachers in the Pilot group differed a great deal about the vernacular translations of the given conceptual terms. They appeared reluctant to commit themselves to naming the concepts which they know to be different in English by only one name. Mk took a long time in thinking. However, teacher Paul said the boys did not "have" the necessary quantity; he was not even sure himself whether it was power or energy the boys did not "have" but he was sure that it was matla they did not "have". He admits openly that the concepts energy, force, momentum and power are all "matla's" even on direct confrontation. This matla translation was shown in Appendix 21 which is the collection of all translations of African subjects of the Student group which are similar to the translations of the Pilot group. The list shows that matla/amandla is the term for energy, force, momentum, impulse and power in the vernaculars of these subjects.

5.3.7 If A outruns B, what does A have that B lacks? (in vernacular)

When two or more people are in a race, one person usually breaks the tape before the others to win the race. What does this person have which others are lacking? What does A have which B lacks that B is being outrun? This entity that A has was needed both in English and in vernacular from 120 research subjects in the investigation.

TABLE 5.9

If A outruns B, what does A have that B lacks? (in vernacular)

INS	N	PMA	EMA	FMA	MMA	SLJ	P	E	F	S	OTHE
		%	%	%	%	%	%	%	%	%	%
UNQ	21	5(1)	10 (2)	10 (2)	-	-	14 (3)	29 (6)	19 (4)	10 (2)	5 (1)
B	4	-	25 (1)	-	-	25 (1)	-	-	-	25 (1)	25 (1)
BN	44	2 (1)	5 (2)	-	-	5 (2)	11 (5)	32 (14)	5 (2)	30 (13)	11 (5)
TAU	5	-	-	20 (1)	-	20 (1)	-	-	20 (1)	20 (1)	20 (1)
TS	6	17 (1)	33 (2)	-	-	-	-	33 (2)	-	-	17 (1)
T3	21	19 (4)	24 (5)	-	5 (1)	14 (3)	5 (1)	14 (3)	-	10 (2)	10 (2)
T2	19	16 (3)	5 (1)	-	-	11 (2)	16 (3)	11 (2)	-	16 (3)	26 (5)
TO %	120 100	10 8	13 11	3 3	1 1	9 8	12 10	27 23	7 6	22 18	16 13

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
EMA :Energy/matla/amandla
FMA :Force/matla/amandla
MMA :Momemntum/matla/amandla
SLJ :speed/lebelo/jubane
E :Energy
S :Speed
UNQ :University of the North - QwaQwa

BN :Bonamelo
TAU :Taung
TS :Teachers
T3 :Tshiya College-3rd year
T2 :Tshiya College-2nd year
TO :Total
P :Power
F :Force
OTHE : Other responses
B :Boitjhorisong

Results

Table 5.9 shows the results: 23% (27/120) indicated that A had more matla/amandla than B, and translated the matla they gave into power, energy, force or momentum. 8% (9/120) gave the answer for the entity as lebelo/jubane translated as speed. 57% (68/120) gave the terms power, energy, force, momentum and speed as answers, but did not translate. 13% (16/120) gave answers different from those expected including matla/amandla and other translations. Answers given were stamina, confidence and strength. Some questions were left blank.

Comment

Matla/amandla was still the entity that was generally accepted as the answer. It was translated into either power, energy, force or momentum.

5.3.8 X and Y are rolling up boulders. X arrives at the top ten minutes before Y since X has more ... than Y (in vernacular)

It is difficult to roll boulders up the hill. However, X was found to be quicker than Y when both were engaged in rolling almost identical boulders up the hill. What was the reason, what is it that X had that Y lacked?

TABLE 5.10
X and Y are rolling up boulders. X arrives at the top ten minutes before Y since X has more ... than Y (in vernacular)

INS	N	PMA	EMA	FMA	MMA	SLJ	P	E	F	M	OTHE
		%	%	%	%	%	%	%	%	%	%
UNQ	22	9 (2)	9 (2)	9 (2)	-	-	14 (3)	41 (9)	9 (2)	9 (2)	-
B	4	75 (3)	25 (1)	-	-	-	-	-	-	-	-
BN	44	-	5 (2)	-	-	5 (2)	30 (13)	34 (15)	2 (1)	18 (8)	7 (3)
TAU	5	-	-	20 (1)	-	20 (1)	20 (1)	20 (1)	-	-	20 (1)
TS	4	50 (2)	-	-	-	25 (1)	25 (1)	-	-	-	-
T3	25	36 (9)	16 (4)	-	4 (1)	12 (3)	8 (2)	12 (3)	-	-	12 (3)
T2	20	10 (2)	10 (2)	-	-	10 (2)	15 (3)	5 (1)	-	30 (6)	20 (4)
TO %	124 100	18 15	11 9	3 2	1 1	9 7	23 19	30 24	3 2	16 13	11 9

INS :Institution
N :Number of subjects
PMA :Power/matla/amandla
EMA :Energy/matla/amandla
FMA :Force/matla/amandla
MMA :Momentum/matla/amandla
SLJ :Speed/lebelo/jubane
P :Power
E :Energy
M :Momentum
OTH :Other responses
UNQ :University of the North - QwaQwa

B :Boitjhorisong
BN :Bonamelo
TAU :Taung
TS :Teachers
T3 :Tshiya College- 3rd years
T2 :Tshiya College- 2nd year
TO :Total
F :Force

Results

Table 5.10 shows the results: 34% (42/124) gave the terms power, energy, force, momentum and speed, together with their translations. Of this total 27% (33/124) gave matla/amandla as the answer and their various translations as power, energy, force and momentum and 7% (9/124) gave speed as an answer translated into lebelo/jubane including the word isipidi, which is speed "Zulufied". 58% (72/124) gave untranslated responses of power, energy, force, momentum and speed. 9% (11/124) gave answers like faster, stamina, gravity, with translations and the others were left blank.

Comment

Matla/amandla was consistently considered as the answer even though English answers were clearly different. There were 58% who did not give vernacular words. 34% did give some vernacular words.

Boitjhorisong Interview Extract (Appendix 14)

What do you think Mistress about this [the interviewer calls her by the title the children use at school for a lady teacher]?

Lele: I think what it really stresses is the fact that we do have problems with Sotho when we teach, because most of the words, force, energy and power, in Sotho is matla. We can't express what type of matla.

Uniqwa Interview Extract (Appendix 15)

I: What do you think about the questionnaire? - [Long Silence] - Nothing?

U1: [the names were not given hence these Uniqwa subjects were labelled U1,U2 etc] I think we do not like to translate to our language...in English and then translate it to our language...we are repeating the same word over and over, like for instance talk about force in Zulu is amandla.

I: What about power ?

U1: The same thing with power

I: So what do you think about our African languages ?

U1: To me it is poor - forget !

[The rest of the group was conspicuously passive to the invitation to the interview. The interviewer needed to be tactfully polite to be acceptable and be able to continue].

I: What did you write? Did you write in Sesotho?

U1: I wrote in English.

[U1 was the only responding person in the group. The investigator, suspecting the students are shied away by English, added in Sesotho though the subjects in Uniqwa are mixed language-wise].

I: Molato ke eng ka Sesotho (what is wrong in Sesotho)?

U1: Re loketse ho sebedisa mantswe a mang, jwale Sesotho ha se na wona (We must use different words which Sesotho does not have)...

U2: [Interrupted] Ha se na mantswe, ke hore ho buuwang e le hore Englishing a teng, mantswe ao a English ha a yo ka Sesotho (Sesotho does not have appropriate words, those words used lavishly in English are not present in Sesotho)...

U3: [Interrupted] Mantswe a English a mangata ha a yo ka Sesotho (most English words do not exist in Sesotho).

The chatting was becoming lively in Sesotho with interruptions.

I: What would you think if I say we should teach physics to Zulus in Zulu, to Sothos in Sotho...?

All: No! It won't be right!

Comment

Teachers admitted the apparent vocabulary limitations of their African languages. Lele in Boitjhorisong had been teaching physics in high school for many years, and she had a University degree with physics as a major. Her contribution that the lack of differentiating words was a problem in teaching must be taken seriously, because she must have experienced this problem over many years in which she was teaching physics. The Uniqwa subjects openly admitted the

African languages' poverty by supplying one word for several conceptual terms. All subjects indeed, show the problems brought about by the undifferentiated conceptual terms in vernacular.

5.3.9 Comments on interviews

The attitude of the subjects was perturbing when they indicated unpleasantness with the investigator when the investigation sessions were long, say longer than half an hour. This happened in almost all institutions. Impatience was aggravated when the investigator discussed some concepts and disagreed with the subjects. English was not the best accepted medium for open and free discussions. When Sesotho or Zulu was included, resulting in a language mixture, depending where it was, in some discussions, most subjects came alive again. Rollnick (1988) came across this attitude among Swati students where mixed language became the best for discussions.

5.4 SPEED - VELOCITY - ACCELERATION

Speed, velocity and acceleration in African languages in South Africa were not distinct words that were differentiated, but rather all seemed to mean just the movement, which could imply any way the position of the object in question changed with time. The investigator viewed the understanding of these students as being that they observed or visualised this change in position with time becoming more and more as the boulders fell lower and lower. This change of position with time was translated as lebelo/jubane, being undifferentiated as speed, velocity or acceleration. Would the language undifferentiatedness not contribute to conceptual difficulty in differentiation? It was the question to be answered. Learners would therefore have problems as to which word in English to choose as a correct translation of the lebelo/jubane concept they had in mind.

Task 2 (shown in Appendix 5) in the language theme investigated the translation of the concept terms for speed, velocity and acceleration. Translation of force would also be investigated, particularly as compared to the translations that were given for energy in the preceding task. The aim in this task was again to investigate the effect of the mother tongue interpretation of these concept terms compared with the physics conceptualization of these related but distinctly different concepts. Table 5.11 is a summary of the responses gathered from the subjects. Indications were given to the subjects that the vernacular terms were essential.

TABLE 5.11

Speed - velocity - acceleration in vernacular

INS	N	S LJ	S B	S S	V LJ	V B	V V	A LJ	A B	A A	F MA	F B	F F
		%	%	%	%	%	%	%	%	%	%	%	%
UNQ	13	31 (4)	46 (6)	23 (3)	23 (3)	46 (6)	31 (4)	8 (1)	54 (7)	39 (5)	23 (3)	54 (7)	23 (3)
B	4	100 (4)	-	-	100 (4)	-	-	75 (3)	25 (1)	-	100 (4)	-	-
T3	21	24 (5)	62 (13)	14 (3)	19 (4)	71 (15)	10 (2)	10 (2)	81 (17)	10 (2)	29 (6)	52 (11)	19 (4)
T2	21	57 (12)	33 (7)	10 (2)	10 (2)	76 (16)	14 (3)	10 (2)	71 (15)	19 (4)	29 (6)	57 (12)	14 (3)
BN	42	64 (27)	21 (9)	14 (6)	41 (17)	45 (19)	14 (6)	36 (15)	50 (21)	14 (6)	50 (21)	45 (19)	5 (2)
TO	101	52	35	14	30	56	15	23	61	17	40	49	12
%	100	52	35	14	30	56	15	23	61	17	40	49	12

INS :Institution
N :Number of subjects
SLJ :Speed/lebelo/jubane
SB :Blank (No response) for speed
SS :Speed given as speed in English alone
VLJ :Velocity/lebelo/jubane
VB :Blank (No response) for velocity
VV :Velocity given as velocity in English alone.
ALJ :Acceleration/lebelo/jubane
AB :Blank (No response) for acceleration
AA :Acceleration given as acceleration in English alone
FMA :Force/matla/amandla
FB :Blank for force in vernacular
FF :Force given as force in English alone
UNQ :University of the North - QwaQwa
B :Boitjhorisong
T3 :Tshiya- third year group
T2 :Tshiya - second year group
BN :Bonamelo
TO :Total

Results

Table 5.11 shows the results: 101 subjects from four institutions were involved in this task. 52% (52/101) of these subjects translated speed as lebelo for Sotho groups and as jubane for Nguni groups. 35% (35/101) did not give answers or gave vernacular coined terms, such as "isipidi" which is a Zulu word coined from "speed" and isivinini which would be given as meaning velocity or acceleration hence it was inconsistent; while 14% (14/101) stuck to English alone in the question that needed translation of the conceptual term, speed.

The same subjects were asked to translate velocity into their own language and 30 of the 101 (30%), responded with lebelo/jubane. 56 (56%) of them gave no answer at all, while 15% of them mentioned only the English name, velocity.

The third conceptual term to be investigated was acceleration. The results were that 23 of these subjects (23%), translated acceleration as lebelo/jubane depending upon Sotho or Nguni. 61% gave no translation or some inconsistent coined terms such as "mafura" in Sesotho meaning fat, or "mafutha" in Zulu also meaning fat, the mafura/mafutha idea taken from the fact that it was always said that the vehicle accelerator was a fat giver to the vehicle; while 17% gave no vernacular term but only gave acceleration.

Comment

Among these teachers, lebelo for the Sotho group population in South Africa, and jubane for the Nguni group, seemed to be widely accepted as the word for movement or the change in position with time, be it speed, velocity or acceleration. The descending order of the numbers that translated the required terms into lebelo/jubane was noted as 52% (52/101) for speed, 30% (30/101) for velocity and 23% (23/101) for acceleration. It was, however, interesting that teachers who were ready to teach physics to pre-university students, should be reluctant to translate the concepts they knew to be different using the same vernacular word, hence more subjects fell into the more uncommitted categories of blank responses and English alone. A reasonable conclusion could be that they had noted the undifferentiated nomenclature of their vernacular for what they have learned as different.

It was, again, very interesting to note that the other two alternative categories of these subjects had the ascending order, but their rates of ascending differed considerably. The category that did not give answers at all increased for speed, velocity and acceleration: 35%, 56% and 61%, while the category that only used English and avoided translation were: 14%, 15% and 17%. The higher rates of ascending non-response suggested the spirit of discomfort among the subjects, while the lower rate of English alone could be due to more confusion and uncertainty. These two categories, where one category gave no response to the request, and the other remained with English alone, were both understood by the investigator as a result of confusion among these teachers in the Pilot group. It was, therefore, not necessarily that the teachers did not know what to write, but indeed, it was embarrassing to write the same word for the concepts that one has discovered in the classroom were distinctly different, even though they were related. Teacher Mk (Appendix 9) indicated this difficulty when he battled and failed to find different words where people ordinarily used matla for all the concepts in question. Teacher Paul (Appendix 10), however, stated it clearly that "Ke matla kaofela" (they are all matla).

5.5 THE BIBLICAL VERSE

A minor task which also fell under the same classification of language difficulties consisted of a translation of a verse from the Bible. When Africans learned languages they used every possible means from all angles to achieve their purpose. The example was how the investigator and his contemporaries learned English. It was not explained to them that English would differ according to the disciplines in which it was used: that the defence force, police force and air force in the military discipline were not the same forces of attraction or of repulsion defined and used in mechanics or physics in general; that energy, force and power were not synonymous in mechanics as in everyday communication where to be forceful, to be energetic and to be powerful meant the same as shown in a short interview with Mavlyn (Appendix 11); that the Christian power in the Blood of the Lamb would not mean the rate of doing work or the rate of dissipation of energy was not easy to distinguish.

A minor task of a Biblical verse was introduced to show how many terms were meaning matla/amandla from a Biblical point of view, which could confuse a mechanics learner if an explicit line was not drawn or emphasis made that the speech or the language of the Biblical verse was strictly in the "religious kind of expression", as it should be done in cases of mechanics teaching.

This minor task was considered by the investigator as important in that the African students in South Africa were heavily evangelised with the Bible of the Christian religion. Since it was so widely used, English Bibles were used by most students among the indigenous population to learn English language construction. The investigator in this project learned much of the English he presently knows by using the Bible translations everyday. He was astonished to discover that Biblical English was not necessarily the same as physics English.

Results

The Biblical verse, paraphrased as shown in the second page of Task 1, last item, about God "who gives us strength with mighty power, far above all authority, all power, against forces of evil by the right to be His children". The aim in this task was to show how the ordinarily spoken language, as well as the authoritative Biblical language which was supposed to be understood well and not be mistaken, both appeared to be different from the language used to express physics. Table 5.10 shows how the distinctly different concept terms were generally translated by students and teachers, who all were the subjects in this study. All accepted unanimously without influencing one another that all underlined words should be rightly translated to matla/amandla. Typical examples of translations were as follows:

From the Sesotho Bible:
ya re neang matla, ka matla a matla, ka hodima matla ohle, matla ohle kgahlanong le matla ohle a bokgopo ka matla a ho ba bana ba Hae. (Sesotho)

TABLE 5.12 Matla/Amandla from the Bible

ENGLISH	strength	mighty	power	authority	force	right
NGUNI's	amandla	amandla	amandla	amandla	amandla	amandla
SOTHO's	matla	matla	matla	matla	matla	matla

From the Zulu Bible:
osinika amandla, ngamandla anamandla, ngaphezu kwamandla onke, mandla onke, maqondana namandla onke obubi ngamandla okubangabantwana bakhe. (Zulu)

Comment

There were some occasional differences from the general translation which was considered correct from the majority of the subjects. Setswana, for instance, in its several dialects, had a synonym to matla as thata; although the two words have the same meaning, to sound different, the two words were used interchangeably.

Yo re fileng maatla ka thata ya gagwe...
Yo re fileng thata ka maatla a gagwe...
(who gives us "maatla" with His "maatla"...)

The accepted Bible translations into the African languages also stated the conceptual terms in this verse all to be matla or maatla (Sotho), amandla (Nguni), maanda (Venda).

5.6 STUDENT GROUP

Of the Student group described in Section 3.4.3, 71 subjects had African languages spoken in South Africa as their vernaculars. They were all in first year university physics in the University of Natal, Pietermaritzburg, in the first semester of 1996. 15 of the subjects were enrolled in Physics 110S (for engineers and physics majors) while 56 were enrolled in Physics 110B (for life science students). Conceptual terms which were given as responses to the task which was handled in Chapter 4 were to be translated into vernacular in order to investigate language difficulties the subjects might have. Of the several languages the subjects used, those with Zulu as home language were 47 subjects, with Sesotho were 5 subjects, for Setswana were 4 , for Xhosa were 7, with Venda was 1 and with Sepedi were 4 subjects; there were 3 Tsonga speaking subjects but they did not translate into Tsonga.

In the following sections the results of translations to questions on Task 1 are presented. The concept term that was given as the English response is given followed by translation terms from various subjects and the number of subjects who gave the response. There were those terms which were unexpected and untranslated responses that were considered as well.

As boulders rolled or fell down the mountain, they gained some mechanics quantities or entities. What these mechanics concepts were, was given in Chapter 4 (Section 4.2). However, the translated responses are given in this section.

5.6.1 As boulders rolled down, which quantity or quantities did they gain?

Translations:

Table 5.13 shows the responses. There were 47 responses given by the subjects in Zulu, Xhosa, Venda, Sesotho and Setswana. Some were correct according to the Chapter 4 Reference group, some were translated into vernacular terms, some were untranslated while some were incorrect. The conceptual terms which were given as responses were Energy (kinetic), momentum, speed, velocity and force.

There were 7 other responses with their translations and some without, such as enemy /lenaba, kamoka/together both in Sepedi; collision/ukushayisa, acceleration/amafutha and much death/ukufa kakhulu in Zulu. Kinetic Energy was given alone untranslated in one response. The rest of the subjects did not respond.

For energy, momentum and force, maanda, matla and amandla were given by various subjects; for energy, speed and force, the Zulu word umdlandla appeared; For force, momentum and energy, amandla appeared. For speed and momentum jubane and lebelo appeared. Jubane also appeared under "other" terms as well with acceleration. [The numbers following the vernacular terms in Table 5.13 represent the number of responses giving the same vernacular term for the concepts opposite it].

TABLE 5.13

As boulders rolled down, which quantity or quantities did they gain... (in vernacular)

	Zulu	**Xhosa**	**Sesotho**	**Setswana**	**Sepedi Venda**	**Untransl-ated**
Kinetic Energy	**umfutho8 amandla6 umdlandl a 1**	-	**matla 1**	**kgokolog-o 1**	**maanda1**	**1**
Moment-um	**amandla2 jubane 1**	**isantya 1**	**lebelo 1 sekgahla1**	-	-	-
Speed	**umdland-la 1 jubane 2 kushesha 1**	-	**lebelo 1**	-	-	-
Velocity	**isivinini 1**	-	-	-	-	-
Force	**amandla1 umdlandl a 1**	-	-	-	-	-

5.6.2 When a boulder collides with a neighbouring boulder, which quantity or quantities does it impart to its neighbour?

52 responses were gathered from the subjects on this question in Zulu, Xhosa, Setswana and Sesotho. Some were untranslated. The mechanics concept terms which were given as responses were Energy (Kinetic), momentum, force, acceleration, velocity, speed and mass (Table 5.14).

TABLE 5.14

When boulders collide, what quantity or quantities do they impart in vernacular?

	Zulu	Xhosa	Sesotho	Setswana	Sepedi	Untranslated
Energy	amandla 2	-	-	kgokologa 1	-	1
Momentum	umfutho2 isisindo4 amandla2 jubane1 nqubuzano1	-	sekgahla1	-	--	4
Force	umdlandla 2 dudula 1	-	-	-	-	1
Acceleration	isivinini 1	isantya 1	-	-	-	1
Velocity	jubane 1	-	lebelo 1	-	-	4
speed	isivinini 3	-	-	-	-	-
Mass	amandla1 isisindo 1	-	-	-	-	-

There were 13 "other" responses with their translations such as friction/kgotlhagano in Setswana and potential energy/umdlandla and pressure/isisindo. Energy, momentum, force, acceleration and velocity were given in some responses but were not translated, others were blank.

Again amandla was given by different subjects to mean energy, momentum and mass in Zulu. Now isivinini appeared to mean both acceleration and speed unlike in the previous question where speed and acceleration were given jubane in Zulu

5.6.3 Some falling boulders can kill a man. For such a boulder to kill a man it have a large amount of ...(appropriate quantity)

There were 45 responses which were gathered from the subjects of the Student group. The correct conceptual terms for this question were Kinetic energy and momentum. However, the subjects gave energy (Kinetic), momentum, weight, mass, speed, power and force in their responses. In Table 5.15 most of these responses were given vernacular words in Zulu, Sesotho, Setswana and Sepedi.

TABLE 5.15

Some falling boulders can kill. For such a boulder to kill a man it must have a large amount of ... (the quantity or quantities in vernacular)

	Zulu	Sesotho	Setswana	Sepedi	untranslat-ed
Kinetic Energy	amandla 2 umfutho 2	-	-	-	-
Momentum	amandla 2 nqubuzo 1	-	-	-	-
Weight	umfutho 2 isisndo 4 umdlandla2 ubunzima 1	boima 1	thata 1	-	1
Mass	amandla 1 isisindo 14	boima 3	-	-	-
Speed	umfutho 1 kushesha 1	-	--	-	-
Power	amandla 2	-	-	maatla 1	-
Force	umdlandla2 umfutho 2	matla 1	-	-	-

There were eight "other" responses from the subjects which, including their translations were: collision/ukungqubuzana and impulse/ingqubuzo.

Energy, momentum, mass and power were translated amandla, maatla and thata. Umfutho was given by several subjects as a word or a translation for the conceptual terms energy, weight, speed and power. Umdlandla appears to mean weight and force.

5.6.4 Some small boys could not even move the boulders; in terms of mechanics concepts, in what ways are the boys different from men?

45 responses were gathered from the subjects. The vernacular terms were given only in Zulu and in Sesotho. While the correct response according to the Chapter 4 Reference group was that the boys could not exert or apply sufficient force, the responses which were given by the subjects

were that the boys had less or insufficient energy, power, force, mass and weight (Table 5.16).

TABLE 5.16

Some small boys could not even move the boulders; in terms of the mechanics concepts, what was the difference between boys and men in vernacular?

	Zulu	Sesotho	Untranslated
Less or not enough Energy	**abanamandla 6 abanamfutho 2**	-	-
Less or not enough Power	**abanamandla 7**	**ha ba na matla 1**	-
Less or not enough Force	**abanamandla 4**	**ha ba na matla 1**	-
Less or not enough Mass	**abanasisindo 3**	**ba fokola 1**	-
Less or not enough Weight	**abanamandla 1**	-	-

Others

There were nine (9) other responses as to in what ways boys were different as compared to men, responses such as: the boys had no experience/botlhale in Setswana, and had no strength/amandla, muscles, were not fully developed/akukaqini in Zulu.

For boys who supplied less energy it was said "abanamandla", less power, "abanamandla", less force, "abanamandla" and less weight "abanamandla"; less power, "ha ba na matla", less force, "ha ba na matla".

General responses from most of the research subjects were that boys did not "have" that particular quantity, had less of that quantity or applied less of the particular quantity, i.e. boys had no force, less force or applied less force (the general responses and translations of the question 4 by the Student group appear in Appendix 21).

5.6.5 Man X and man Y are rolling identical boulders up the mountain. Man X arrives at the top ten minutes before man Y. Describe the differences between man X and man Y rolling the boulders in terms of the mechanics concepts.

There were 50 responses which were collected from the subjects for this question. The vernaculars were Zulu, Sesotho and Sepedi. Some were untranslated. The correct response according to the Chapter 4 Reference group, is that man X generated more power. The subjects gave power, force, energy and acceleration as responses (Table 5.17).

TABLE 5.17

Man X arriving at the top ten minutes before man Y. The difference between X and Y with vernacular translation.

Difference	Zulu	Sesotho	Sepedi	Untranslated
Energy (kinetic)	-	sekgahla 1	-	1
Power	umfutho 3 amandla 5	-	-	3
Force	amandla 3 umfutho 3	sekgahla 2	maatla 1	3
Acceleration	-	lebelo	-	2

There were nineteen (19) other responses that were not expected; most of them were not translated, such as: man X had greater mass, man X had greater strength, man X is eating properly and man X is strong.

Power and force were translated or given the vernacular word amandla by some Zulu subjects, and umfutho by others. Energy and force were given sekgahla in Sesotho by the subjects who translated.

5.7 GROUPS COMPARED (PILOT AND STUDENT)

It was important to establish if the vernacular terms given by the subjects were the concepts in vernacular or were the English concepts translated into subjects' vernacular. The problem started with the Reference group of the language difficulties which consisted of African physics lecturers and post-graduate students in various universities in South Africa. They did not give responses which were "correct and complete" compared to the responses of the Reference group of the theme of Conceptual difficulties. Despite the instruction given that their responses should be both in English and in mother tongue, most of them still gave responses in one language, either in English or in mother tongue. As the tables show, there was a general reluctance to give the conceptual terms in vernaculars both among the Pilot and Student groups.

For the quantity or quantities gained as boulders rolled down, 32% of the Pilot group gave matla/amandla for Kinetic energy, momentum, force and power; while 42% of the Student group gave the mixture of matla/amandla and umdlandla (which also was a kind of amandla and also courage) for these concepts.

For the quantities imparted when a boulder collided with a stationary boulder 17% of the Pilot group gave the mother tongue term matla/amandla for power, kinetic energy, force and momentum which were given as the English responses, while 40% of the Student group gave several different mother tongue terms for the same terms.

For the quantity the boulder must have much of in order to kill a man, 24% of the Pilot group gave matla/amandla for power, kinetic energy and force which were given as responses, while 61% of the Student group gave a variety of mother tongue terms for the same concepts but with mass also included in the responses.

For the difference between men and boys in moving boulders when boys could not even move some boulders, 32% of the Pilot group gave matla/amandla for power, Kinetic energy and force while 34 % of the Student group gave different responses excluding matla/amandla for the same conceptual terms plus weight.

For the difference of man X and man Y when man X arrives ten minutes before Y at the top, 34% of the Pilot group gave matla/amandla for power, kinetic energy, force, momentum and lebelo for speed, while 61% of the Student group gave a variety of mother tongue terms for power, kinetic energy and force which were given as the English responses.

It was therefore noted that the Pilot group was greatly limited to matla/amandla while also that they were reluctant to give the vernacular words. The highest percentages where the Pilot group gave the vernacular terms is 34%. It was either that there was no vernacular term for the concept, the subjects did not know it or they were reluctant to repeat it if they used it before for a different concept.

Translation of these concept terms by the Pilot group indicated that indeed there were problems. Those subjects who did translate showed that the various English concept terms were translated in an inconsistent way by synonyms or were undifferentiated in African vernaculars in the South African context, terms such as amandla, umdlandla and umfutho in Zulu which were usually used interchangeably as shown in Steve and Mike when interviewed (Appendix 24). Such undifferentiated terms "mislead" students to conclude that various concept terms in the English used in physics are synonymous just as it is in everyday English communication, particularly if the emphasis is not made that the language spoken in physics needed to be very special. The translations done by the Student group were different in that they used additional words such as umdlandla (still matla in Sotho languages), which was still synonymous with amandla. This umdlandla was not a consistent translation of any particular term. Thus the Student group appeared to have a richer vocabulary in vernacular which they could associate with mechanics concepts than the Pilot group. Even so, there was little consistency among the Student group in how the various vernacular terms were used, a problem also observed with the Reference group.

5.8 SUMMARY

If the ten English terms that mean matla/amandla in some sense, namely force, energy, power, momentum, right, authority, strength, might, strong and majesty, did have explicit meanings that could be differentiated, the difference was not very apparent to the African learner who grew up in the communities that did not differentiate these terms. Rather the learners would have difficulties not only in separating the terms as they should be separated, but probably also in understanding the actual concepts referred to by these terms. The same difficulties would be experienced by the learners with the conceptual terms speed, velocity and acceleration. Rutherford and Nkopodi (1990) show how problematic the comparisons of the concepts are between the two languages, namely English as language of instruction and the home language of the learner, be it Zulu or Sesotho. In addition, there were several vernacular terms that could be used to refer to various concepts in mechanics, but neither the Reference group nor the Africans in the Student group agreed on which vernacular terms correspond to which English terms.

CHAPTER SIX

THE OUTCOME AND THE CONCLUSIONS

6.1 INTRODUCTION

The aim of this study was to investigate difficulties among African learners in understanding several concepts in mechanics and how their vernaculars affected their learning of those concepts. However, there were several other difficulties which were hurdles to the learning and understanding of mechanics, physics or even science in general, which were excluded in this study as variables, such as those outlined in by Seretlo (1973) in the Overview, in Section 1.1 and those given in The limitations of the Study in Section 6.4.

In this chapter the various findings summarised; the relationship between the research study and the literature reviewed is outlined, and the limitations of this study to adequately investigate the difficulties of the African students globally are discussed. The discussions are based upon the observations and data analysis from among the pre-service teachers and in-service teachers who had been teaching high school physics in the Qwa-Qwa region as the Pilot group. These findings were compared with the responses from the Student group consisting of first year physics students at the University of Natal, Pietermaritzburg. The results were collected from subjects in several Teacher Training Institutions, Colleges of Education and Universities. The investigations of these difficulties were considered post instruction. Since Task 1 originated from the experience of the investigator, who considered the Moshoeshoe's wars story as a practical example of cross-cultural physics familiar to African people (Opalko 1991), it had no direct reference in the literature except the history books which relate it. On the other hand, the Quiz Question in Task 2 was familiar from the extensive research work on similar difficulties done around the world (Watts and Zylbersztajn 1981; Clement 1982; Halloun and Hestenes 1985; Rollnick 1988; Jegede and Okebukola 1990). The results of these international researchers were compared with the results obtained from the Pilot subjects of this research study, who were all African students in typical South African institutions where much less research had been conducted on these difficulties (Grayson 1994a).

The conceptual difficulties among the African subjects in this study were similar to those noted by McDermott (1991). She noted that students did not respond correctly, not because instructors failed to present the course content clearly and correctly as viewed from a physicist's perspective, but usually because what the instructor or the remedial material taught or implied and what the student interpreted or inferred as having been taught or implied were not the same.

New findings related to the identification of a quantity that the subjects indicated was intrinsic to a person or object. This quantity was usually identified by a single term matla/amandla in the vernacular of the research subjects, but reverse translation into English resulted in the inconsistent use of a number of mechanics terms. A lack of consensus among African physicists and students was also identified with respect to the correspondence between several vernacular terms and English mechanics terms.

6.2 FINDINGS AND COMPARISON WITH THE LITERATURE

FINDINGS

There were ten findings made in this study from the observations. Some were similar to those findings already observed elsewhere by other researchers, while some were surprisingly new. The findings are classified below:

General Comparison

1 African subjects' performance was poor in mechanics compared to that of ethnic groups that used English as first language in South Africa.

Conceptual Difficulties

2 Correct force conceptualisation among African teachers in the Pilot group was lower compared to that of the subjects of the international researchers.

3 African subjects mostly gave only one term in their responses even where more than one could be given.

4 Most African subjects considered the concept "matla/amandla" as an intrinsic quantity.

5 Some of the study subjects had a misconception that one needed to have mass or weight at least equal to that of the boulder if he or she was to succeed to roll it.

Language Difficulties

6 Reverse translation (from vernacular to English) of vernacular terms was apparently used in the responses where mechanics terms force, energy, momentum and power were given resulting in confusion of the choice of appropriate conceptual term in English.

7 Most subjects understood the four distinct mechanics concepts, namely power, energy, momentum and force to be synonymous and found them difficult to distinguish one from another.

Difficulties Intertwined

8 The vernacular terms matla and amandla did not convey any distinction between the different mechanics terms into which they could be translated.

9 Some English speaking subjects successfully used verbs associated with mechanics quantities while the African subjects did not generally associate correct verbs with the quantities.

10 Distinct concepts of mechanics stated in English did not have consistent counterparts in African vernaculars according to the Pilot, Student and Reference groups. There was no consensus on vernacular counterparts.

LITERATURE REVIEWED INFORMING THE STUDY

This section contains a comparison of the reviewed literature with what was found in the present study concerning the difficulties investigated. The misconceptions referred mostly relate to the "coin toss" task since the Moshoeshoe's wars and Task 3 were the two tasks newly introduced in the present study.

6.2.1 General Group Comparison: The Pilot against the Student

A general comparison of the correctness of the responses given by the subjects from the Pilot and the Student group were made for the questions in Task 1 and Task 2. The correctness of the responses was determined by the Reference group in Chapter 4 which consisted of physics lecturers and professors from several universities. The correct responses from the Student group were divided according to ethnicities for White, Indian and African subjects and compared with those of the Pilot group. Table 6.1 below summarises the results of Task 1. On the results of Task 2, the "coin toss" task, similar results are observed. Table 6.2 summarises the results of Task 2 about forces on the rising ball.

TABLE 6.1

Percentages of correct responses given by the Pilot group and by each sub-group in the Student group to Task 1

Question No.	Pilot Group	Student Group		
		Whites	Indians	Africans
1	79	96	69	69
2	38	84	81	61
3	16	46	25	23
4	13	54	41	31
5	33	26	6	29

TABLE 6.2

Percentages of correct responses given by the Pilot group and by each sub-group in the Student group to Task 2

Position No.	Pilot Group	Student Group		
		Whites	Indians	Africans
1	2	52	34	32
2	35	62	59	37
3	62	86	69	53

The responses on question 5 of Task 1 were interesting. It was the only question which was answered correctly by more African subjects than others followed by White students then Indians. The investigator suggests that this fact was influenced by reverse translation. Most responses were given to be matla/amandla by the African subjects of both the Pilot and the Student groups. Most of these subjects knew "power" as a reverse translation for matla/amandla in most of the five questions, which was incorrect except in question 5 where power was incidentally the right answer. Hence they gave the right response, not necessarily because they understood it to be right, but by the coincidence that power was chosen as the appropriate term upon reverse translation.

Conclusion

Although there were a few exceptions in the pattern of the results, the indication was that the general responses given from the subjects in the Student group followed some trend such that White subjects appeared the best, while the Indian subjects appeared better than African subjects in the understanding of these mechanics concepts in question. The African teachers in the Pilot group appeared to show the least understanding. More specifically, for most questions, the performance of the African teachers was worse than that of African students studying first year university physics. Thus the physics knowledge of the teachers in this study was generally at a low level.

6.2.2 Conceptual Problems

Task 2 has been used by many researchers around the world in the investigation of the understanding of their students as far as force is concerned. This task was used in this study to determine how the results of the South African students and teachers compared with those of their international counterparts. Task 1 was an original set of questions introduced in this study to further probe the conceptualization of force, momentum, kinetic energy, speed, velocity and power.

1 Comparison with International Student Difficulties

Numerous physics researchers around the world used a task similar to Task 2 which involved a ball or a stone thrown upwards, where force on this object were required from their subjects. Among many results which were given, 85% of the subjects used by Watts and Zylbersztaijn (1981) from Surrey in England indicated the presence of an upward force on the rising ball, 66% of the subjects used by Osborne (1985) stated there was a continuing upward force, 69% of the subjects in the study of Gilbert, Watts and Osborne (1985) from New Zealand had the idea that the ball was acted upon by an upward force, 88% of the subjects in the study of Sadanand and Kess (1990) from Connecticut indicated the upward force and 52% of the subjects tested by Sequeira and Leite (1991) from Braga in Portugal indicated this upward force. All the subjects with whom the above researchers worked were investigated post instruction. The subjects in the present study were in-service and pre-service teachers, also investigated post instruction.

98% of the Pilot group in this study stated the presence of the upward force while the ball was going up, while the percentage of the subjects of the Student group who gave responses indicating an upward force are: Whites: 48%; Indians: 66% (both having English as vernacular) and Africans: 69%.

55% of the Pilot group indicated the presence of an upward force on the ball at the highest position, namely position 2, while the subjects of the Student group indicated the presence of the upward force as follows: Whites: 36%; Indians: 28% and Africans: 60%.

26% of the subjects in the Pilot Group indicated the presence of the upward force on a falling ball at position 3, while the subjects of the Student group showed the presence of the upward force on the falling ball as follows: Whites: 14%; Indians: 28% and Africans: 47%.

The following quotation from the interview with Teacher Ma (Appendix 17), illustrated the type of thinking underlying the misconception:

I :What would you say to somebody that would say there's never an upward force after the ball has left the hand?

Ma :How come the ball has gone upwards without the force upwards?

Comparison with the Literature

The results were similar to what the international researchers observed in their studies such as in Watts and Zylbersztajn (1981) where 85% of the subjects associated the force with motion as in this study. Most subjects in this study labelled the "pushing" or "applied" force from the thrower as the force acting upwards on the ball as was noticed in Clement (1982). The majority of the subjects in the study conducted in McDermott (1994) indicated an upward force indicating the idea of "motion implies force". Osborne (1985) had 66% of his subjects having the same "upward force" problem who did not abandon it even after appropriate instruction. Most international and local researchers such as in Seepe (1993) and in Grayson (1995) noted how their subjects associated force with motion, the higher the speed, the higher the force and in the same direction of the force causing and maintaining the motion. However, the 98% of the Pilot group subjects in this study, who believed in the upward force, was the highest figure reported, even higher than the 87% observed in Thijs and Van der Berg (1994). Considering the fact that the Pilot group consisted of teachers, this finding has serious implications. Since it was teachers like these who taught the African students, this also probably partially explains why the African students in the Student group did worse than their peers.

Conclusions

1 The force misconception, that there was an upward force on the three positions of the ball, namely, on the way upwards, at the highest position where the ball turned around and at the position where it was falling back downwards, existed among the African subjects who were the subjects of the study, as it did among the subjects of the international researchers mentioned.

2 This force misconception was relatively more prevalent among the African subjects compared to other subjects. In the Student group the African subjects' responses are poorer than those of Whites and Indian subjects. That is, the force misconception under investigation is more common among African subjects.

3 The belief in the existence of an upward force of the ball when it was moving upwards, was very much more prevalent amongst the teachers in the Pilot group than amongst any of the Student group. This suggests poorer understanding of the physics concepts amongst the teachers than amongst the first year university students.

Matla/amandla elaborated

Task 1 had ten questions originally, which were answered by the Pilot group. These questions were rephrased and their number was reduced to five which were answered by the Student group in this study. However, in both versions the aim was to investigate if the subjects understood how the mechanics concepts force, momentum, kinetic energy and power differed and whether the subjects could readily identify these concepts where they occurred.

Most African subjects indicated that these concept terms had a single term in their vernaculars: matla in Sesotho, Setswana and Sepedi (Sotho group) and amandla in Xhosa, Zulu, Swati and Ndebele (Nguni group). Zulu and Sesotho dictionaries and authorities in these languages were consulted for the authoritative meaning of matla in Sotho group term and amandla in Nguni group term.

Casalis (1981) in The English-Sesotho Vocabulary gave the Sesotho term for force as "matla", for energy as "matla" and for power as "matla" while momentum did not appear in the vocabulary. Mabille and Dieterlen (1985) in their Sesotho-English Dictionary gave matla as meaning force and strength.

Doke, Malcolm, Sikhakhana and Vilakazi (1990) in their Zulu-English, English-Zulu Combined Dictionary indicated amandla to mean "mighty", "strong" and "powerful".

The investigator used the Bible translations to learn most languages spoken in South Africa since that proved to be the easiest and the cheapest method to learn other languages. There was a likelihood that his many other African colleagues learned other languages in a similar manner. The minor task incorporated in the Moshoeshoe's wars task, which needed translation of a Biblical verse, indicated how twelve distinguishable terms in English were indistinguishably translated as matla/amandla.

The Constructivist's ideas could therefore be applied to this case of the matla/amandla concept in the following manner: Cobern (1996) from Arizona, who focused his attention on non-western students with non-western cultures, proposed that students constructed knowledge under the influence of prior observations of their surrounding world; he warned that students from different cultures would have different perspectives to western science, which he suggested must be incorporated into their knowledge structure. Since according to the theory of Constructivism, learning occurred when there is a knowledge input to the learner resulting in new construction of sense over and above the learner's current understanding of the world around them, it could only be concluded that in the African perspective the matla/amandla concept that had been constructed, in their own sense and according to their own understanding, was that quantity causing motion.

Conclusion

It was, at this juncture that the investigator suggested that African students in South Africa appeared to use a concept constructed as " matla/amandla" which was an entity or a quantity contained in objects or systems universally to cause some motion or change in position. There was no line drawn to separate and differentiate matla/amandla from one context to another different context: in mechanics, politics, religion, traditions, economy and otherwise. All twelve terms, namely, force, energy, momentum, impulse, power, strong, might, mighty, strength, strong, privilege and right are translated as matla/amandla.

"Amandla!" was the well-known political quantity in South Africa which was so much "power" that it replaced one strong government regime with another. In teacher Paul's interview (Appendix 10), for energy, force, momentum and power he said "Hantle, ke matla kaofela (exactly, all are matla's).

2 Single Term

In surveying the responses to question 1 of Task 1 by the Pilot group, only 5 subjects out of 106 gave more one response. 24 said speed alone, 31 said energy (kinetic) alone, 22 said force or acceleration or anger or vigour. 95% of the subjects gave only one term for the response where they could have given three correct terms, when the instructions said give as many terms as possible. While the Student group subjects were not interviewed, one factor noticeable among the teachers in the Pilot group who were interviewed was the frequent need for prompting "and anything else" by the investigator when the subjects were just giving one term and appeared satisfied. The Student group responses showed how rife it was among African subjects to give just single term responses as for example in Table 4.15 where 32% (16/50) of the White subjects gave "complete and correct" responses while no African subjects gave any "complete and correct" responses but 63% (48/76) gave correct and incomplete responses. The tables which show the kinds of responses the subjects gave, such as Table 4.15, 4.17, 4.19 and 4.21 show that the African subjects gave more "correct but incomplete" responses than other ethnic groups in the Student Group.

Table 4.13 which summarises the subjects' understanding of acceleration, velocity and speed, confirmed the idea that only one term was given in most responses for the movement with time, either speed, velocity (which were correct according to the Reference group) or acceleration.

Literature Information

This difficulty of learners in noticing the distinction among speed, velocity and acceleration has been recorded by researchers such as Trowbridge and McDermott (1980, 1981), Minstrell (1982) and Grayson (1990).

As Cobern (1996) suggested, these Africans should be allowed to construct their world view their own way. For almost all questions of the tasks, most African subjects gave a single term as a response. Since most African subjects appear to have thought there was only one vernacular term, namely matla/amandla, only one English term was given as the concept constructed as matla in their response to any of the questions. Mr N gave the single response "matla" for four of the questions in Task 1. Teacher Paul gave all five responses in Task 1 as matla even though he was aware that the responses were distinctly not the same.

Conclusion

Most African subjects gave only a single term as response even where there could be three or more possible correct terms. The conclusion could be that the African people had only constructed a single concept of the quantity "matla/amandla", for example, which was gained as the boulder was rolled down. Only one term was therefore constructed for the four concepts, namely power, energy, momentum and force.

3 Matla/amandla intrinsic

From Section 4.5.4, in the discussion of the difference between boys and men in that men could roll the boulders which boys could not even move, there appeared a list of responses as to how the boys were different from men. The Sotho group of subjects said men "ba na le matla" (men have matla) or boys "ha ba na matla" (boys have less or no matla) and Nguni group of the subjects said men "banamandla" (men have amandla) or boys "abanamandla" (boys have less or no amandla).

There were few of the subjects who have English as their home language who said that boys "have" force. However, this idea that boys "have" force was very prevalent among African learners in this study. Incidentally, "have" implies that the quantity has to be one's property, or be one's entity which one can impart or give away or keep it or even walk around with it within himself. Such a quantity would be intrinsic to, say the boy. This is the meaning of "they have matla", implying that matla is not the quantity which gets applied or exerted between two or more objects but a property belonging to a single object.

Literature Information

This idea of "has force", "have force" referring to a moving object or even "the force it has" was noted by Watts and Zylbersztaijn (1981), Watts (1983) and Grayson (1990), while presently among these African subjects it was the phrase that indicated the reverse translated idea of "possessing" or having the "force" within oneself. It clearly indicated the presence of the misconception that these quantities were believed to be intrinsic among most of these subjects. Before the inception of this study, the investigator himself believed that most of these quantities were intrinsic as well.

Conclusion

Since the correct response to the question asking for the quantity needed by the boys was force, it was a quantity which could not be intrinsic if it was understood well. It was an interaction between two or more bodies or objects. It could not be intrinsic to a single body. This idea "to have" indicated that the subjects believed that the quantity was intrinsic, which was an incorrect understanding.

4 Mass - Weight Misconception

Several subjects in the Pilot group, 11 out of 119 subjects, (9%), stated that if either the mass or the weight of the boys were smaller than that of the boulders then the boys could not even move the boulders. This idea appeared among the Student group where the response distribution of those who said boys could not move the boulders since their mass or weight was smaller than those of the boulders they needed to move was as follows: Whites: 6% (3/50); Indians: 22% (7/32) and Africans : 17% (12/70).

The following extract from the interview with Teacher Ma (Appendix 17) illustrates the type of thinking involved:

I :Let us go to the fourth question. Some small boys could not even move some boulders. Now in terms of some mechanics concepts, what is the difference between boys and men?

Ma :The difference is their mass. For these to roll boulders up, they need a certain amount of weight.

From the argument of this teacher Ma the mass of the boy in kilograms should contribute to the quantity that was "needed" to roll the boulder. To roll the boulder of 1000N he had to be able to exert 1000N which was contributed by the mass he had; since the mass the boy had contributed to some force or the weight of the same boy, the force which needed to be "exerted" appeared to be a quantity intrinsic in the boy since it was due to his mass or weight, although it was said to be exerted. The meaning of force being exerted appeared here not to be understood as an interaction between bodies but appeared to be intrinsic to the boy concerned.

One member of the Reference group in Chapter 4 had this weight misconception. Lecturer J. also had this misconception such that he said that boys had "isisindo esincane" (smaller mass/weight).

Literature Information

This misconception was similar to the one which was noted by Gunstone and White (1981), Watts and Zylbersztajn (1981) and Grayson (1990) using the Atwood machine where their subjects believed that a lighter object could not lift or cause a heavier object to move.

Conclusion

This misconception that the subjects believed that a person needed at least the mass equal to that of the object he/she must push or roll, otherwise it could not be rolled or pushed successfully, was an interesting misconception. While it was seen amongst 9% of the Pilot group, the Student group exhibited this difficulty as follows: Whites : 6%; Indians : 22% and Africans :17%. This was the second category where the African learners were not the worst. This misconception also appeared to indicate that the subjects thought the force was intrinsic in the boys, depending on the mass or weight they had, who needed to move the boulders.

6.2.3 Language difficulties

Language difficulties were also shown to contribute to African learners' problems in understanding physics. For example, when the ball was thrown up, African learners knew that it could not go very high if not much matla/amandla was given to it. The more matla/amandla given, the higher it would go. African vernaculars, as was seen in Table 5.2, treated power, energy, force and momentum as matla/amandla undifferentiated. The study subjects then, when asked about forces on the rising ball, probably understood the question in mother tongue, and indeed, matla/amandla was carrying or pushing the ball upwards. The problem was the reverse translation from mother tongue to English. 98% of the teachers in the Pilot group translated matla/amandla as force, probably because they were led by the question to think about force. They were wrong to say that there was an upward force, but there was an entity upwards, although not force but momentum; they recognized that entity and that entity was generally accepted amongst them as matla/amandla. It was however, likely to be a matter of reverse translation that they called it force and not energy or momentum. If the question needed momentum on the rising ball 98% could still have said there was an upward momentum, because they would have been led to momentum which is also matla/amandla. More research needs to be performed in this area.

1 Reverse Translation

Seretlo (1973) voiced the problem of African languages in expressing physics concepts such as the situation where weight, mass and density were all isisindo in Zulu and there were no terms for numerous physics concept terms. Rollnick (1988) supported the idea that students not taught in their own mother tongue had difficulty in language clarification to the extent of resorting to mixed language of say SiSwati and English for clear expressions in inter-student discussions. In general, therefore, studying in the second language appeared to be very problematic.

Teacher Paul insisted in his interview (Appendix 14), that all concepts in Task 1 could only be translated into matla in Sotho group vernaculars. In Chapter 5, the English responses shown in Tables 5.3 through 5.7, from numerous subjects on question 1, 2, 3, 4 and 5 were spread across force, energy, momentum and power but were in the majority of cases translated into matla/amandla. In Table 5.3, 25% of the 31% who gave the vernacular word for the English terms they gave translated momentum and energy as matla/amandla. In Table 5.4, 29% who gave the mother tongue words, gave power, energy, force and impact as matla/amandla; in Table 5.5, the 17% who gave the vernacular terms gave power, energy, force and momentum as matla/amandla. It is in this question where 2% of the subjects left matla as it was, untranslated.

Similarly the interview of teacher Ma showed (Appendix 17), how "lebelo" was the quantity that was seen to be gained as the boulders rolled down the mountain; the problem was to translate "lebelo" into the teacher's vernacular which was Sesotho. Teacher Ma said acceleration was being gained as the boulders rolled down. Most subjects translated "lebelo" into either speed, velocity or acceleration as seen in the results of Task 3 which was only given to the Pilot group.

Literature Information

It was therefore in this case where it was certain that while matla was always the sure vernacular response, the problem was the English mechanics terms to which matla/amandla was to be translated. This daily life situation, where a single word is used to refer to two or more distinct concepts has been noted by Champagne, Gunstone and Klopfer (1985) and by Grayson (1990).

McKinley et al (1992), working among the Maori in New Zealand, discovered similar problems in the translation of some conceptual terms and concluded that since language interacts with thinking, translation of thoughts from one language to another can never be perfect.

Conclusion

The conclusion drawn here was that the subjects understood that the mechanics quantity involved in all the questions about the boulders was matla/amandla. The problem was to translate it. The matla/amandla and the lebelo/jubane translation difficulties showed that the subjects first started with the terms in their languages then translated into English which was where they had problems.

2 Matla/amandla undifferentiated

Grayson (1996) in her paper to the summer meeting of the American Association of Physics Teachers indicated that physics learning was difficult for students receiving instruction in mother tongue, while it was even more difficult for those who studied it in a second language, particularly those whose mother tongue was limited in its scientific vocabulary. She said this referring to African students studying physics in South Africa. Sanders and Sebego (1966) illustrated how one word had many different translations with various meanings which could not be understood if the language to which translation was desired, was not culturally familiar to students.

In section 6.2.2 above, under "single term only" it was indicated that the study subjects gave only one term in their responses even though some questions answered could have up to three concept terms as correct. Most of these terms which were given as responses were translated with only one term by those who did give a translation: energy as matla by (Sotho group) and amandla (by Nguni group), power was matla/amandla and force was matla/amandla.

The African learners, therefore, are likely to have their learning and understanding influenced by their languages and cultures. Due to the lack of emphasis as to how the concepts in mechanics, physics and science as a whole should be separated from the daily life expressions and loose conversations, there was no line of demarcation drawn among the terms of mechanics, religion, politics and otherwise. The minor task of Biblical verse confirms this observation. Altogether twelve English terms could be "translated" as matla or amandla; they could subsequently be regarded to have the same meaning of matla/amandla; they are hence considered synonymous so that there is no need to write more than one of them if they all meant "matla/amandla".

Literature Information

It was at this point that African learners would be justified if they had difficulties in differentiating among the four mechanics conceptual terms since they had only constructed a single concept in the place of all five, that was matla/amandla in the place of force, momentum, energy and power. It was however, surprising that Watts and Zylbersztajn (1981) reported about English speaking students used "force" when they really seemed to mean momentum; Watts (1983) reported about students using "force" where a physicist would use energy or power. One wondered what could be the cause of this difficulty in differentiating these conceptual terms among the English speaking students while African learners were justified in that they had only one conceptual term for all four terms.

Conclusion

If the investigator looked at the responses in vernaculars, subjects in the Pilot group mostly gave one response namely matla/amandla. It could be concluded that matla/amandla was seen to be the right response, but that the difficulty was into which of the four terms to translate matla/amandla. This conclusion was two-way:

1 Subjects only saw matla/amandla in their home language which was only one "mechanics" quantity in their own sense;

2 It was here where it was seen that the understanding started with the vernacular term matla/amandla and the struggle was into which English term to translate the vernacular term. It could therefore not be right to translate into more than one term if only one term in vernacular was seen to be correct, and the subjects could not note the difference hence the reverse translation into several concept terms, which might well have been regarded as synonymous.

6.2.4 Difficulties Intertwined

Literature Information (Matla/amandla language concept)

The matla/amandla issue which surfaced as the difficulty of subjects only giving single term answers as responses to questions which needed different although related mechanics terms as response, further supported the idea that students first implement their mother tongue understanding on the particular concepts and then struggle to translate it back to the language it originally had been in. This back translation is in keeping with the idea of Chomsky (1988) expressed in his Managua lectures how difficult it is to translate a concept directly from one language into another. Pines (1985) advised that a deeper knowledge of language and culture ensured proper transmission of information. Van Hise (1988) warned that the deep seated non-scientific conceptions in a language not clearly understood, disturbed the ultimate understanding of scientific concepts. Rutherford (1993) actually warned that where language discrepancies such as reverse translations occurred, it was unsafe in the end to assume that the learner had the same meaning of the concept as that described by the teacher. Dooms (1995), referring to Sutton (1980), Vygotsky (1962) and others stated how culture and language together facilitated conceptual understanding leading to knowledge construction.

1 Matla/Amandla language concept

Section 5.6 shows the confusion of the translations, how matla/amandla was translated into all the four concept terms in the everyday language (and how speed, velocity and acceleration were translated into lebelo/jubane by the Student group as well). This everyday language used carelessly when translated distracted from the understanding of the scientific meaning of the concept (Jacobs 1989).

The percentages of the correct responses from the subjects on question 5 of Task 1 were interesting, namely Whites, Indians and Africans: 26%, 9% and 29% respectively in the Student group against 33% of the Pilot group. The correct percentage was reversed from other tasks. The most likely explanation of this correctness reversal, where more Africans in the Student group and the Pilot group were correct than the Whites and the Indians in the Student group, could be supplied as follows: The responses in all questions of Task 1 were thought to have been "matla/amandla" in the African vernaculars. In most cases matla/amandla was "known" to mean power in both everyday language and the popular political slogans of the present day in South Africa. Task 1 was specifically constructed to unearth the problem the investigator had always been having of the ability to differentiate among the mechanics conceptual terms energy, momentum, force and power. The aim was to have the terms energy, momentum, force and power involved to investigate if the study subjects would successfully both identify and differentiate them one from another.

Another interesting observation was that Mr N, who was regarded as an authority both in Physics and Sesotho, who was in his post-graduate level of study, gave all the untranslated responses as "matla" for every single question where four of the above-mentioned conceptual terms were expected. Mr S was a teacher the investigator was referred to by the Science Education Division of the Education Department of the Natal University in Pietermaritzburg. He was the one trusted to respond to the questionnaires the best both in English and in Zulu. He was involved in producing teachers who prepare the students in the matric level Physical Science. He was then consulted. He gave amandla as the responses to all five questions of Task 1, he also translated all the four conceptual terms, namely power, energy, momentum and force as amandla. Teacher Paul is a Physical Science subject advisor in the Free State Province. He had not studied to post-graduate level in Physics. However, teacher Paul had for a long time being teaching matric Physical Science. In his interview (Appendix 10), he declared that all the four terms, energy, momentum, force and power were all matla. He did not give all concepts correctly, but he insisted that matla was correct as the response. He said for instance, boys did not have as much power and energy as men did in order to move boulders. However, to him both energy and power are matla.

2 Associated Verbs

The Reference group on Task 1 consisted of physics lecturers and professors from different institutions. They strictly associated the mechanics quantities they mentioned with some specific verbs, such as: force applied or exerted, energy dissipated, work done and power generated or power expended. The investigator had not been this strict in applying these verbs as the members of the Reference group. A case in point was seen in the responses to question 4 of Task 1.

The importance of these verbs was that they appeared to go together with the understanding of how the mechanics quantity should be handled, together with a proper understanding of the said verb. One subject gave the response that "the boys could not apply sufficient energy". Someone knowing enough English applied to mechanics would know that energy could not be applied but it was expended or dissipated. Knowledge of proper verbs would help with the proper conceptualization of the particular mechanics quantity.

Of the subjects who were regarded as correct by stating that the force was the difference between men and boys, some subjects associated the quantities with particular verbs; some correctly said boys could not exert sufficient force, some said they could not apply enough force, some incorrectly said they did not have force while others just mentioned force as the difference.

Table 4.6 showed the results of the Pilot group. Of the 16% (19/119) of the subjects who correctly responded with force as the difference between boys and men, 4 stated that force applied was not sufficient, 2 said force exerted was not enough, 5 wrote of "their force" or the force they had (apparently intrinsic) and 8 mentioned just force as a response.

Table 4.22 showed the results of the Student group. Of the 31 English speaking White subjects who responded with force on the question, 36% (11/31) wrote force applied, 42% (13/31) wrote force exerted and 23% (7/31) just mentioned force. Of the 18 Indian subjects, who also have English as their home language, 17% (3/18) stated that force was applied, 39% (7/18) force was exerted and 44% (8/18) just mentioned force. However, of the 32 African subjects 41% (13/32) wrote force applied, 13% (4/32) wrote force exerted, 28% (9/32) just stated force while 19% (6/32) stated that the boys did not "have" sufficient force.

Literature Information

Touger (1991) warned that teachers and textbook writers must be made aware of the need to avoid loose "locutions" such as "force acts" or "force pulls", but should rather say "force exerted by one body on another body". They needed to be careful about "forces on X" in the place of "forces exerted on X". He warned that the teachers need to be much more specific.

Sporadic incorrect verb associations were also found among the Reference groups, such in the case of a professor who said the boys did not "have" enough force in the place of "boys could not exert enough" force. Even textbooks contain such errors. For example, The book C. S. E. Physics (Appendix 9) by Nelkon stated: "We say X has greater power than Y".

Conclusion

Verbs associated with particular quantities indicated the understanding of the particular quantity by the subjects. Subjects not conversant with these associated verbs would struggle in understanding the mechanics concepts. However, there were some research subjects who used these associated verbs in wrong associations. For example teacher Mm said "not enough energy was exerted", which showed an incorrect association.

3 No consensus on Conceptual Terms in Vernacular

The aims in the investigation of the Language difficulties in the understanding of mechanics concepts among the African subjects included determining if there were consistent African vernacular terms for mechanics conceptual terms which would facilitate the differentiation of one concept from the others among the related mechanics concepts such as power, momentum, energy and force or speed, velocity and acceleration. A Reference group for this vernacular terms investigation was put together, made up of African physicists. Where they were asked to give vernacular terms for every response they gave in Task 1, most study subjects, both in the Pilot and Student groups, did. Teacher Paul in his interview said "Ke matla kaofela" (they are all matla). However, the following difficulties were noted with the responses from the Reference group:

1. they did not agree on the responses in English, i.e. they were not unanimous

2. the vernacular terms they gave for particular conceptual terms were different from one person to another

3. in most cases they gave fewer responses than were expected.

The following were examples as seen in Section 5.1.1:
On the third question of Task 1 where a quantity was needed with which a boulder must fall in order to kill a person, Mr N said matla/power, Mr Q said energy and did not give a vernacular word, and the investigator said kinetic energy/sekgahla. They totally disagreed in their responses as well as in the translations they gave for the English mechanics conceptual terms they gave as responses. A wide inconsistency was noticed in Section 5.1.1. From the general comments on the responses from the vernacular Reference group in Section 5.1.2 and African subjects in the Student group, there was indeed no consensus as to the real and consistent meaning of the conceptual terms in South African vernaculars. Matla/amandla was used for several distinct terms in mechanics, lebelo/jubane as well.

Literature Information

Similar results amongst English-speaking students were reported by Grayson (1990) and Champagne, Gunstone and Klopfer (1985) where a single word was used for several distinct conceptual terms or in Trowbridge and McDermott (1980,1981) where velocity and acceleration were not easily distinguished from one another.

Conclusion

While the Pilot group mostly used matla/amandla to refer to the four related mechanics terms, responses from the Student and Reference groups showed that not only African students but even African physicists do not agree on which vernacular terms and which English mechanics terms correspond. One English term was translated into different vernacular terms by the subjects, and conversely one vernacular term was translated into different English terms. Such confusion in translations must surely lead to difficulties in understanding the associated concepts.

6.3 THEORY ON THE STUDY IN GENERAL

White (1988) stated that concepts which are associated, such as force kinetic energy and momentum, are often confused, although they differ widely in their meanings. Indeed this confusion among force, kinetic energy and momentum can result in learners mistaking these concepts, one with another. Touger (1991) stated an example from a student revealing such a confusion as follows: " energy is the power a thing has of doing work". It was noted from the results of international physics education researchers that most subjects refer to an "upward force". This confusion was found to be rife among the subjects of the Pilot group.

It therefore became apparent that most of both the Pilot and Student groups in this study did bring these confusions to their classes and they were not empty slates or "tabula rasa" as stated by Osborne (1985), McDermott (1991), Van Heuvelen (1991) and Reddish (1994).

It is the theory of constructivism that states that these concepts, faulty as they may be, are constructed in the minds of the learners or study subjects in order to make sense of their worlds, and are often very resistent to any change, challenge or eradication. Indeed, the subjects in this study had these confusions or deep-seated misconceptions which were constructed in their minds and were not discarded by most of them even long after instruction.

These misconceptions or confusions constructed in the minds of the subjects, appeared further to have been aggravated by the language of instruction. Translations between English and vernacular turned out not to be consistent among even the members of the language Reference group. Such warnings were sounded by researchers such as Vygotsky (1962), Seretlo (1973), Pines (1985) and others in the cited literature. They stressed that languages served a dual purpose of thought and communication. Apparently to most of the study subjects matla/amandla was the concept constructed in their minds as the entity involved in the motion of the objects. In this matla/amandla concept there was no separation among force, kinetic energy , power and momentum. Hence matla/amandla poses a difficulty in being understood as any of the four concepts. Sanders and Sebego (1996) warned about terms in some languages where each term has various meanings depending on the construction, and the confusion such words or terms could cause.

Having constructed non-scietific concepts in their minds and having brought such misconceptions to the class, the misconceptions were resisıant to any conceptual change even long after much instruction were given. The resistance was shown in this study by 98% of the Pilot group who indicated the existence of on the upward force acting on the object which has left the hand in the "coin toss" task (Task 2).

6.4 ABOUT THE INVESTIGATOR

The investigator had been lecturing physics in the University of the North for the previous twelve years prior to this investigation. He had learned much in order to conduct a research study with valid and reliable results in the courses he studied in Statistics and Operation Research. The following were, among others, what he performed in this study:

1 Articulating the questionnaire

Task 1 is the original work from the investigator. While the intention was to identify the difficulties African students have with concepts in mechanics using a true story familiar to the subjects of the study, unlike foreign ones used in American or British books, the investigator still had a problem of phrasing and articulating neutral and non-leading questions.

When the investigator was constructing the questionnaire, originally, while only piloting, he was not so accurate about the technique as to how the questions were phrased in order to yield unbiased responses. However, he reworded and reduced the questions for the Student group from which the actual investigation was done. For example, while the responses in the original questions were just one word, either force, momentum or energy, in the reworded questions deeper investigation was achieved with the aid of associated verbs, and information was obtained about the implication of the conceptual term to be intrinsic and vernacular terms. The analysis of how matla/amandla translation contributed to misconception and confusion in understanding the mechanics concepts was shown in the list of direct translation of phrases which were given as responses to question 4 by the African subjects (Appendix 21) in the Student group.

It was at this point that it had be mentioned that the wider analysis was made only on question 4 in the reworded Task One because it was mainly this question reworded in such a way that it yielded responses that could be analysed in a variety of ways, such as the kind of conceptual term, the concept being intrinsic, the verb used in association with the concept term, the phrases used in the translations and the vernacular words for the English term. This question was the most fruitful question in the investigation of the understanding of the mechanics concepts by the study subjects in that it afforded the investigator a chance of wide scope of analysis unlike those questions which were phrased only to provide a single word as a response.

2 Only determining difficulties and not how to combat them

This study only identified the difficulties which the African teachers and students have in learning and understanding mechanics concepts. These difficulties were not considered to be all the difficulties of the African students since they were limited to the difficulties of only in-service and pre-service teachers and university students. There were many other difficulties in this learning which affected other kinds of African students in South Africa, such as the Secondary and Primary Schools Physical Science students where they studied with no laboratory equipment, for instance.

It was a hard work to unearth these difficulties while piloting among the teachers with the aid of this methodology and the data collected. The piloting led to the main of identifying the difficulties among the Student group subjects, the main research subjects. More studies in other populations among these African learners and teachers are recommended. Research on teaching interventions to combat the difficulties identified could be helpful. It needs another study on its own to determine how the difficulties unearthed in the present study can be combated. The approach and the methodologies would be different from the ones used in this study.

6.5 LIMITATIONS OF THE STUDY

The study which was carried out here was limited. It only determined the difficulties in learning and understanding a fraction of the Physics curriculum (mechanics) by a fraction (teachers only on piloting and students of the University of Natal alone) of a particular population (African) group.

1 Not for all Physics Concepts (mechanics only)

Many kinds of studies could be carried out in the field of Physics Education beyond this study. For example, a study conducted among Science Foundation Program students at the Pietermaritzburg campus of the University of Natal showed how the students revealed difficulty in understanding the difference between heat and temperature. Grayson (1994a) showed how Zulu students battled with the alternative ideas they had about lightning and electricity; the investigator in the issue of "The Binding Energy" (Appendix 12), indicated how Uniqwa students had problems in understanding the binding "energy". In short, this study, which was limited only to the investigation of the understanding of a few concepts in mechanics, was just a small part of a wide study which could be carried out in Physics Education in South Africa.

2 Not for all difficulties (conceptual and language only)

This study only investigated conceptual and language difficulties. There were numerous possible difficulties, some of which were excluded as variables. There were socio-cultural difficulties for instance, such as a Christian student encouraged to believe in the power in the blood of the Lamb against the definition of power from physics. It would be difficult for a student to understand these concepts if socio-economically his or her family could not provide him or her with food and clothing or if the school building was so dilapidated that students were always cold and dusty or even when the school work was very rarely done due to stay away and class boycotts by both students and teachers. All these were difficulties which were not investigated as to how they contributed to the learning and understanding of mechanics by these African students.

3 Not for all African students in the Country (only in Pietermaritzburg and Qwa-Qwa)

While this study might have been done over the whole country of South Africa among the African teachers and students as the research population, limitations such as travelling expenses and time compelled the study to be performed in the North Eastern Free State region of Maluti in Qwa-Qwa which was neither very urban nor very rural, and in Pietermaritzburg, with the study leaving out the places which were very rural and those which were very urban. The results and the findings put together from this study were admittedly limited in adequacy and accuracy. Wider study needed wider travelling, more manpower, more time taken from formal classes with numerous variables observed and kept constant. Such a study would be valuable and could be achieved with more funding and trained research man-power.

4 Not revealed that Africans can learn Physics if properly taught!

This study was not wide enough to investigate and prove that African learners could learn and achieve the necessary understanding of Physics like subjects from many other ethnic groups. It was the investigator's opinion that if the physics teachers of these African subjects conducted good research as to how they could appropriately teach their students to achieve successful results, more African learners could do well in Physics and not be scared away as the investigator's professor had done (Appendix 20). It was interesting to note that even from that class among whom the professor declared that Physics was not for the "Bantus", yes, amid all the derogatory statements of the lecturers that did not bother to overcome the African difficulties in learning Physics, a student ultimately succeeded in Physics beyond the high level of studies to become a professor in Physics in that particular university. University of Fort Hare, an Historically Black University, succeeded over the years to produce African graduates in Physics. Indeed, unlike the statement that Physics and Mathematics were not for Africans and women, it could be shown that it was possible to become an African physicist. African students who went through the Science Foundation Program of the Maritzburg Campus as well as those who did not, have managed to go beyond the Masters level of study in that University. Indeed, given a sincere teacher who knew how to address the difficulties such as those investigated in this study, successful learning and teaching in Physics was possible despite the noted problems. In the neighbouring countries, such as Lesotho, it was not a difficulty to learn and succeed in Physics. Surely, as it was said, if Physics lecturers in South Africa could note these difficulties experienced among Africans learners and act positively, remarkable results could be achieved.

6.6 IMPLICATIONS AND RECOMMENDATIONS

1. A comparison between African teachers' performance in responding to questions investigating their understanding of mechanics concepts and University of Natal first year physics students, showed that African teachers' performance in general was the poorest comparatively speaking. The majority of these Africans used incorrect concepts or conceptualized mechanics differently from physicists. From the findings above these misconceptions were probably caused by concept construction in the language and culture situation of these students and teachers. As Osborne and Freyberg (1985) proposed, it was the duty of the physics teacher as a diagnostician and a researcher about the students' general difficulties, to establish how these general difficulties could be combatted.

2. Most African students had difficulties in identifying forces on an object thrown up and going on its own that were similar to their counterparts in the outside world; only that more African teachers in the study showed these difficulties. Grayson (1990), Watts and Zylbersztajn (1981) and Watts (1983) did notice that some of their subjects identified concepts differently: force for momentum and force for energy and power. It was found that 98% of the responses from African teachers showed they believed the force to be still acting on the ball as it goes on its own long after the hand had been removed. Why did the majority of these teachers believe in this? Further research about appropriate concept identification is therefore necessary beyond this study.

3 Most African subjects in the study gave only one term for all the matla/amandla related terms, presumably because they were seen to mean a single concept in their mother tongue. It was therefore difficult to differentiate these conceptual terms. As Seretlo (1973) warned that for Zulu people for instance, isisindo meant weight, mass and density, and Sanders and Sebego (1996) showed many terms in Setswana which mean several related and unrelated words in English; it was not surprising when these African subjects gave only a single term as a response where force, momentum, energy and power were expected or even where two or three of them were expected. Now that the findings show that the limitation of the African vocabulary aggravated the understanding of mechanics concepts, also as pointed out by Grayson (1996), some research should be performed as to how to alleviate this difficulty. Possibly some coined terms such as a "Zulufied" word "isipidi" as a translation of speed could help, this approach might help address. McNaught (1994) states that African languages do not have the linguistic capacity for scientific explanations although they are rich with ecological concepts. Rollnick (1988) in Swaziland noticed her subjects communicating physics better when using a mixed language. Inglis (1993) in Pietermaritzburg suggested the articulation of scientific ideas in mother tongue and developing them into understandable English. Nangu (1994) advocated translation of concepts into understandable language such as mother tongue for the concepts to be understood. However, a strategy for helpng students know which of the several English terms to use when translating from a single vernacular term would need to be devised.

4 To most African subjects in the study, the phrase "ha ba na Matla/abanamandla" implied that the matla/amandla quantity was intrinsic in the objects or persons involved. Grayson (1990) noticed her subjects in Seattle saying phrases such as "object has force" and from Watts and Zylbersztajn (1981) a phrase "when it is moving, and that the faster an object moves, the more force it has". Although in their cases it was not emphasised as an indication that the force was regarded as intrinsic by this phrase, the phrase of "have force" had been widely encountered in this present study where it was translated to "ha ba na matla/abanamandla" (Appendix 21) by both the Sotho and Nguni groups in clear indication that the mechanics concepts are regarded as intrinsic. A teacher of these

African subjects needs to be not only concerned with the language of instruction when it was the second language to the students as suggested by Inglis (1993), Rutherford (1993) and McNaught (1994), but also needs to transcend beyond into the culture of the students as suggested by McKinley et al (1992) and Thijs, Van der Berg (1994) and Lynch (1996). They state that the cultural factors are so intertwined with language that they could not be separated in successfully carrying the scientific material to be learned across to students for conceptualization.

5 Most African subjects in this study appear first use their mother tongue to interpret and to understand the mechanics concepts being taught; then the reverse translation occurred to express in English or the language of instruction what the student thought was wanted. Dooms (1995) citing Sutton (1980) and Vygotsky (1962), explained how knowledge is constructed in a process influenced by the understanding of the surrounding world conditions (including language). Dooms therefore warned teachers that students had already made sense in their own culture and mother tongue of what they were being taught. Cobern (1996) warned that, for instance non-western students would construct their knowledge in a manner different from the western student both in culture and language. It was when these concepts were understood in mother tongue as proposed above that reverse translation was done into the instructional language, which was not the student's mother tongue, in the reverse translation process. If successful processes of conceptual change were to be achieved, knowledge and understanding constructed though conceptualization with the aid of language and culture, had to be channelled from what already was accepted to be known in the language and culture in which it was found to be accommodated or assimilated into a new realm of the generally accepted knowledge (Hewson and Thorley 1991; Posner et al. 1982; Champagne et al.1985; Wittrock 1985; Pintrick et al. 1993; Hynd et al.1994; Redish 1994). The findings of this study suggested that mother tongue terminology be introduced which would be aligned to science terminology to avoid the difficulties in the process of reverse translations.

6 Specific verbs were used in association with particular conceptual terms to indicate the understanding of the concept by the person expressing it, while the converse was also true

that expressing the concepts with improper verbs indicated a lack of understanding by the learners. Watts and Zylbersztajn (1981) and Grayson (1990) recorded these incorrect verbs which were used by their subjects where the subjects said "an object has force", "the faster it moves, the more force it has". Nelkon (1975) in his book CSE Physics (Appendix 7), stated "We say that X has a greater power than Y". also referred to machines having power. Touger (1991) warned that proper verbs needed to be used in association with conceptual terms. Force is applied or exerted, energy is expended or dissipated, work is done and power expended or generated as stated by the Reference group on the conceptual difficulties in this study. Improper verbs such as "has force", which were often used, must be avoided. Such misconceptions were seen mostly in this study among the African subjects of the study. The understanding of mechanics concepts could be greatly enhanced by correctly using the associated verbs.

7 There was no consensus even among African physicists, about which African vernacular words and which English physics terms correspond. It is recommended that the South African physicists who know appropriate differences among these related but distinct concepts, work out the acceptable nomenclature of these conceptual terms. Such nomenclature would would help solve the problem of the inconsistent identification of these concepts since it would provide clear definitions and standardised translations.

6.7 SUMMARY

African learners in South Africa displayed a number of conceptual and language difficulties. suspected. Difficulties which were identified by international researchers among their subjects were present, but among these African subjects in South Africa these difficulties were worse, possibly because they were apparently aggravated by language and culture.

The African matla/amandla concept was found to be difficult to translate conceptually into physics and into the English language. In fact there were several conceptual terms for matla/amandla that were distinct and differentiated in physics and in English, showing how the two kinds of difficulties were interwoven together, namely conceptual and language. The African vernaculars in South Africa thus proved limited and restricted in conceptual and language translations of mechanics.

The task of Moshoeshoe's wars presented an adequate forum where a "non-western" student, particularly an African student in the remote rural locations of say, the former classified South African homelands, could be introduced to a number of mechanics concepts with the aid of this task; unlike the remedial work and foreign (American and British) books which have unfamiliar examples of "Bunji jumps","Roller coasters" and "Merry-go-rounds".

This task made apparent that in the conceptualisation of the African subjects, men who could move big boulders had more of the entity than boys who could not. When a person who had some of this entity within himself/herself acted on an external body, some of the entity would be transferred to that external body. (Did this mean the person's own store of the entity has been reduced, i.e. was there some conservation of the entity? If so, how was the entity replenished? If not, did a person always maintain a constant amount of that entity within himself/herself?). By contrast, in English, a person had ability to exert a force on an external body (strength) but did not have force within himself/herself. The term "force" is a means of describing an interaction between two or more bodies. When a person exerts a force on a stationary body, that body acquires momentum, not force. When a person pushes a boulder down a mountain, there a force is exerted by the person on the boulder, the boulder gets accelerated, as the person lets the boulder go on its own with the speed it has achieved, the boulder acquires momentum. As it rolls downhill the earth exerts a force of attraction on the boulder and causes its momentum to increase. If this boulder strikes a stationary boulder on the way down, some of its momentum is transferred to that boulder. This momentum can be transferred from one object to another. If one person runs after a second person, while person 1 runs with more speed than person 2. To do this, person 1 must have the ability to generate more energy per unit time, i.e. more power, but does not "have" more power within himself/herself. The ability to generate energy at a fast rate is determined by "non-physics" concepts such as strength and fitness (physiological concepts).

Thus in order to help African learners understand mechanics concepts not only must the distinction among the conceptual terms be made clear, but also the distinction between what is intrinsic to a person and what can be imparted to or acquired by an external body must also be made clear.

CHAPTER SEVEN

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

CHAPTER SEVEN

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

In the overview in Chapter 1 (1.1), it was indicated how poorly African students in South Africa were performing in physical science in their matric, i.e. pre-tertiary examinations. These examination results implied the possible presence of numerous hurdles and difficulties in their studies in physics.

Several factors were eliminated as variables in this research study as outlined in Chapter Three and the research field was narrowed to the investigation of difficulties of African pre- and in-service teachers as well as the University students in freshman physics, in understanding physics in two categories, namely, conceptual and language difficulties.

The study was successfully carried out among school teachers in the Qwa-Qwa region as a Pilot group, who have been teaching secondary school and pre-university physics, and others who were just ready after training, to start teaching. The study was also successful among freshman physics students who were labelled as the "Student group". The investigator selected the research study of investigating difficulties in understanding mechanics, including force because he, being an African student, had problems in this conceptual realm himself, with little confidence that he could satisfactorily answer the questions such as those in practical problems like Moshoeshoe's wars even though he has taught University physics for more than ten years. Force was also a topic that has been widely studied elsewhere, such as in the "coin toss problem" so some comparisons could be made.

7.2 CONCLUSIONS

The investigation into the understanding of concepts, where conceptual translation was involved, showed much confusion amongst the subjects. For example 98% of the African subjects in the Pilot group believed in the upward force acting on a coin tossed upwards.

The general comparison of correctness in responses among students from different ethnic groups showed that the African subjects' responses were the weakest. Most of these concepts in the "matla/amandla" concept group are, in general considered to be intrinsic to the objects applying them by the African subjects.

From these observations and the others which are all laid out in the chapter dealing with the findings, (Section 6.2), it is here concluded that many difficulties exist in the realm of concepts and language as well as both intertwined, which are hurdles in the understanding of mechanics concepts by the African science learners in South Africa.

In general, it was shown by this investigation that indeed these difficulties do exist among the African students. They cause problems of not understanding physics concepts as readily as expected.

7.3 IMPLICATIONS

The conclusions drawn after observing the responses and analysing the data gave the findings that there is a great problem in understanding the mechanics concepts among the African learners. This implies that work must be done to improve the situation of conceptualizing physics among the African learners, both teachers and students in South Africa.

Not only did the subjects fail to distinguish the differences among several related concepts in the research tasks, but it appeared the research subjects did not even realise that such distinctions existed because they were not named differently in mother tongue. An example of such a group is power, energy, force and momentum. Such concepts so related to one another, given the same name in vernacular, appeared to be understood to be synonymous and not different, as shown in the results of this study. Moreover, the conceptualisation demonstrated by the subjects of force as a quantity intrinsic to a person is in conflict with the scientific concept of force.

7.4 RECOMMENDATIONS

Lecturers of physics to African students will, therefore, not succeed in their task until they give attention to these difficulties which these students have. If attention is not properly given, the students will either not succeed in physics, or they will memorise physics concepts and formulae from one level of study to another without understanding, just like the investigator did. He only understood most of these concepts while he was a lecturer, not while he was a student.

Further study is therefore necessary to determine how African students can be helped to appreciate the differences in these related concepts, how speed, velocity and acceleration differ from one another, for example. It can be from such studies where African nomenclature of related concepts may be suggested. Such a nomenclature could simultaneously solve both conceptual and language difficulties because all conceptual terms would have been specifically defined. Moreover, the concept terms should be taught together with appropriate associated verbs, which can enhance conceptual understanding.

An experienced science teacher, Khalipha (Appendix 23) suggested a teaching strategy where a language difficulty was a hurdle in a physics classroom. She assured the investigator that from such strategies, much understanding can be achieved. On applying strategies such as the one Khalipha used, a teacher that has researched the difficulties of the students, and has come to know what their difficulties are, can address the difficulties the students have using a similar strategy or devise any other fruitful strategy. Using the same strategy Khalipha used for "conductor", force can be used to clarify other "forces" such as Police Force, Air Force and Defence Force or Electro motive force.

Strategies need to be devised to facilitate learning and understanding such as coining new words which would be consistent with their definitions. Such coining, however, though very necessary, would not be a sufficient solution to these numerous difficulties. Language problems would have been solved but conceptual problems would still need further attention.

Further strategies, such as Khalipha's highlighting strategy and nomenclature suggestions, are recommended; they can surely combat the problems of understanding physics such as those arising from reverse translations that cause multiple difficulties for African students in understanding physics, as shown in this study.

African physicists also need to get together and agree on meanings of vernacular terms and translations into English. These terms, once agreed on, should be introduced into teacher college and school textbooks and curricula.

7.5 SUMMARY

It was concluded from this research study that African learners had conceptual and language difficulties that affect their understanding of physics. It was further recommended that these difficulties must be adequately understood by the physics teachers of these learners before they can be appropriately and successfully confronted, addressed and resolved. It is then finally concluded that it is necessary that further studies be conducted to determine how to alleviate the difficulties brought about by misconceptions and language difficulties in understanding mechanics concepts, and teaching strategies need to be devised to facilitate better understanding.

BIBLIOGRAPHY

African National Congress. 1994a. A policy framework for Education and Training. Education Department. January 1994.

African National Congress. 1994b. The Reconstruction and Development Programme (RDP). A policy framework. 1994.

Arons, A.B. 1973. Toward Wider Public Understanding of Science. American Journal of Physics **14** : 769 - 782.

Arons, A.B. 1989. Developing the Energy Concepts in Introductory Physics. The Physics Teacher **27** (7): 506 - 517.

Arons, A.B. 1990. A Guide to Introductory Physics Teaching. John Wiley and Sons. New York.

Bauman, R.P. 1992. Physics that Textbook Writers Usually Get Wrong. III. Forces and Vectors. The Physics Teacher. Volume 30, October 1992. 402 - 407.

Bible: Ephesians 1: 19 - 21; 6: 10.

Bliss, J. and Orgborn, J. 1994. Force and Motion from the Beginning. Learning and Instruction. Volume 4. pp 7 - 25.

Burgess, R. G. 1985. Issues in Educational Research. Qualitative Methods. The Falmer Press. Philadelphia.

Bogdan, R. C. and Biklen, S. K. 1992. Qualitative Research for Education. Second Edition. Allyn and Bacon. London.

Casalis, E. 1981. English - Sotho Vocabulary. Morija Sesuto Book Depot. Morija. Lesotho.

Champagne, A. C., Klopfer, L. E. and Anderson, J. H. 1980. Factors influencing the learning of classical mechanics. American Journal of Physics **48:** (12) 1074- 1078.

Champagne, A. C., Gunstone, R. F. and Klopfer, L. E. 1985. Instructional Consequences of students' knowledge about physical phenomena. In L.H.T. West and A.L. Pines (Ed.) Cognitive Structure and Conceptual Change. Academic Press. London. 1985.

Cilliers, J.A., Kirschner, P.A., Basson, I. and Rutherford, M. 1996. Assessment of the Integrated process skills of distance learners in physics in South Africa. A paper read to Education group at the 41st Annual Conference of the South African Institute of Physics in the University of Pretoria in July 1996.

Chomsky, N. 1988. Language and Problems of Knowledge. The Managua Lectures. The M I T Press. Cambridge. Massachusetts.

Clement, J. 1982. Students' preconceptions in introductory mechanics. American Journal of Physics **50:** (1) 66 - 77.

Corben, W.W. 1996. Constructive and non-western science education research. International Journal of Science Education **18** (3) 295 - 310.

Doke, C.M., Malcolm, D.M., Sikhakhana J.M.A. and Vilakazi, B. M. 1990. English - Zulu; Zulu - English Dictionary. Witwatersrand University Press. Johannesburg.

Dooms, P. 1995. Culture, Language, Cognition and the Learning of Science. In A. Hendricks (Ed.) Proceedings of the Third Annual Meeting of Southern African Association fore Research in Mathematics and Science Education. University of Cape Town.

Edelstein, M.L. (1972). What do Young Africans Think? South African Institute of Race Relation. Johannesburg.

Finegold, M. and Gorsky , P. 1991. Students' concepts of force as applied to related physical systems: A research for consistency. International Journal of Science Education **13** (1) 97 - 113.

Finegold, M. 1992. Adapting Physics Curriculum materials across a language barrier: a feasibility study. International Journal of Science Education **14** (1): 13 - 23.

Fowler, F.J. 1993. Survey Research Methods. 2nd Edition. Applied Social Research Methods Series Volume 1. SAGE Publications. London.

Galili, I. and Bar, V. 1992. Motion implies Force: where to expect vestiges of the misconception? International Journal of Science Education. Volume 14, Number 1. 63-81

Gelmann, S.A. and Byrnes, J.P. 1991. Perspective on Language and Thought. Cambridge University Press. Cambridge.

Gilbert, J.K., Watts, D.M. and Osborne, R. 1982a. Students conceptions of ideas in mechanics. Physics Education **17:** 62 - 66.

Gilbert, J.K., Watts, D.M. and Osborne, R. 1982b. Eliciting student views using an Interview-about-Instances Technique. In L.H.T. West and A. L. Pines (Ed.) Cognitive Structure and Conceptual Change. Academic Press. London. 1985.

Graham, C. 1995. The nature and relevance of physics, and present-day challenges the South African physics lecturer. An inaugural lecture at the University of Natal, Pietermaritzburg.

Grayson, D.J. 1990. Use of the Computer for Research on Instruction and Student Understanding in Physics. Unpublished Doctor of Philosophy dissertation. University of Washington.

Grayson, D.J. 1994a. Zulu students' ideas about Electricity. Submitted to Science Education. 1994.

Grayson, D.J. 1994b. Concept substitution: An instructional strategy for promoting conceptual change. Research in Science Education **24**: 102 - 111.

Grayson, D.J. and McDermott, L.C. 1996. Use of the computer for research on student thinking in physics. American Journal of Physics **64**: (5) 557 - 565.

Grayson, D.J. 1995. Science Education Research and Implications for University Science Instruction. South African Journal of Science **91**: 168 - 172.

Grayson, D.J. 1996. Beyond Concepts: Influences that affect students' understanding of physics in South Africa. A paper presented at the Summer Meeting of the American Association of Physics Teachers, University of Maryland.

Gunstone, R. and Watts, M. 1985. Force and Motion. Children's ideas in science, In R. Driver, E. Guesne, and A. Tibergien (Ed.) Children's Ideas in Science. Open University Press, Milton Keynes. England.

Gunstone, R.F. 1987. Student Understanding in Mechanics: A large population survey. American Journal of Physics **55** (8) 691 - 696.

Gunstone, R.F. and White, R.T. 1981. Understanding of Gravity. Science Education. **65** (3): 291 - 299.

Halloun, I.A. and Hestenes, D. 1985. Common sense concepts about motion. American Journal of Physics **53** (11): 1056 - 1065.

Halloun, I.A. and Hestenes, D. 1985. The initial knowledge state of college physics students. American Journal of Physics **53**: 1045-1055.

Halloun, I.A. and Hestenes, D. 1987. Modelling instructions in mechanics. American Journal of Physics **55** (5): 455-462.

Helm, H. 1996. The Physics Lecture: The medium and the Message. A paper read at the 41st Annual Conference of South African Institute of Physics, held at the University of Pretoria. July, 1996.

Hestenes, D. and Wells, M. 1992. A mechanics baseline test. The Physics Teacher. **30:** (1) 159-166.

Hestenes, D; Wells, M. and Swackhamer, G. 1992. Force Concept Inventory. The Physics Teacher. **30:** (1) 141 - 158.

Hestenes, D. 1986. Toward a modelling theory of physics instruction. American Journal of Physics. **55**: (5) 440 - 454.

Hewson, M.G.A'B. 1985. The Role of Intellectual Environment in the Origin of Conceptions: An Exploratory Study. In L.H.T. West and A.L. Pines (Ed.) Cognitive Structure and Conceptual Change. Academic Press, Inc. 153 - 161.

Hewson, P.W. 1981. Conceptual Change approach to learning Science. European Journal of Science Education. **3**: 383 - 396.

Hewson, P.W. and Thorley, N.R. 1991. The conditions of conceptual change in the classroom; International Journal of Science Education **11** : Special Issue 541 - 553.

Hewson, P.W. and Hewson, M.G.A'B. 1983. Effects of instruction using students' prior knowledge and conceptual change strategies on science learning. Journal of Research in Science Teaching. **20**: (8) 731 - 743.

Hewson, P.W. and Hewson, M.G.A'B. 1987. Science teachers' conception of teaching: Implications for teacher education. International Journal of Science Education **9**: (4) 425-440.

Hills, G.L.C. 1989. Students' "untutored" beliefs about Natural phenomena: Primitive Science or Common Sense? Science Education **73** (2) 155 - 186.

Hynd, C.R.; McWhorter J.W.; Phares, V.L. and Suttles, C.W. 1994. Role of Instructional Variables in Conceptual Change in High School Physics Topics. Journal of Research in Science Teaching. **41**: (9) 933 - 946.

Idar, J. and Ganiel, U. 1985. Learning difficulties in High School physics: Development of a remedial teaching method and assessment of its impact on achievement. Journal of Research in Science Teaching **22**: (2) 127 - 140.

Inglis, M. 1993. An Investigation of the Interrelationship of Proficiency in a Second Language and the Understanding of Scientific Concepts. In V. Reddy (Ed.) Proceedings of the First Annual Meeting of Southern African Association for Research in Mathematics and Science Education. Center for the Advancement of Science and Mathematics Education. University of Natal, Durban. 129 - 139.

Jacobs, G. (1989). Word usage misconceptions among first-year University students. International Journal of Science Education **11** (4) 395 - 399.

Jegede, O.J. and Okebukola, P.A. 1991. A relationship between African traditional cosmology and students' acquisition of a science process skill. International Journal of Science Education **13**: (1) 37 - 47.

Kahn, M. and Rollnick, M. 1992. Science Education Research in Africa: How can it help us? In D.Grayson (Ed.) Proceedings of the Workshop on Research in Science and Mathematics Education, held at Cathedral Peak, 20-24 January 1992. University of Natal, Pietermaritzburg, South Africa 68 - 81.

Leedy, P.D. 1989. Practical Research. Planning and Design. Fourth Edition. Macmillan Publishing Company. New York.

Lightman, A. and Sadler, P. 1993. Teacher predictions versus Actual Students' Gains. The Physics Teacher **31** (3) 162 - 167.

Lynch, P. P. 1996. Students' alternative frameworks: linguistic and cultural interpretations based on a study of a western tribal continuum. International Journal of Science Education **18** (3) 321 - 332.

Lythcott, J. 1985. "Aristotelian" was given as the answer, but what was the question? American Journal of Physics **53**: (5) 428 - 432.

Mabille, A. and Dieterlen, H. 1985. Sesotho - English Dictionary. Morija Sesuto Book Depot. Morija. Lesotho.

Marks, R. G. 1982. Designing a Research Project. Van Noristand Reinhold Company. New York.

McCloskey, M., Carmazza, A. and Greene, B. 1980. Curvilinear motion in the absence of external forces; naïve beliefs about motion of objects. Science **210**: 1139 - 1141.

McClosky, M. 1983. Intuitive Physics. Scientific American. April 1983.

McDermott, L.C. 1984. Research in Conceptual Understanding in Mechanics. Physics Today **37**: 23 - 32.

McDermott, L.C. 1991. Millikan Lecture 1990: What we teach and what is learned - Closing the gap. American Journal of Physics **59**: (4) 301 -315.

McDermott, L.C., Shaffer, P.S. and Somers, M.D. 1994. Research as a guide for teaching Introductory Mechanics: An illustration in the context of the Atwood Machine. American Journal of Physics. **62** : (1).

McKinley, E., McPherson Waiti, P. and Bell, B. 1992. Language, Culture and Science Education. International Journal of Science Education **14**: (5) 579 - 595.

McNaught, C.M. 1994. Learning Science at the Interface between Zulu and English. Unpublished. A thesis submitted in partial fulfilment of Ph D degree. University of Natal. Pietermaritzburg.

Minstrell, J. 1982. Explaining the "at rest" condition of an object. The Physics Teacher **20**: 14 - 40.

Minstrell, J. 1994. Teaching for the Development of Understanding of Ideas: Forces on Moving Objects. 1984 AETS YEARBOOK by Anderson, C.W. (Ed.). December 1984

Mohapatra, J.K. 1991. The interaction of cultural rituals and the concepts of science in students learning: a case study of solar eclipse. International Journal of Science Education **13**: (4) 431 - 437.

Moji, N.C. and Grayson, D.J. 1994. African Students' mind and Their Conceptualizing in Physics. A paper read in the South African Institute of Physics Conference in University of Bophuthatswana in July 1994.

Moji, N.C. and Grayson, D.J.1995. Investigation of the effect on Physics learning of Undifferentiated terms in Mother tongue. In A. Hendricks (Ed.) Proceedings of the Third Annual Meeting of the Southern African Association for Research in Mathematics and Science Education Conference. University of Cape Town.

Moji, N.C. and Grayson, D.J. 1996. Physics Concepts in Mother Tongue. In D.Grayson (Ed.) Proceedings of the Fourth Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Natal. Pietermaritzburg.

Moji, N.C. and Moji, V.S. 1993. Education Financing in South Africa: How it was, How it should be. A seminar delivered in the department of Education and Humanities. University of Manchester. December 1993.

Moji, V.S. 1991. A personal conversation on how student nurses in Ga-Rankuwa Hospital had difficulties together with their lecturers with English as the instructional language.

Monk, M. 1994. Mathematics in physics education: a case of more haste less speed. Physics Education. **29** 209 - 211

Moravcsik, J.M. 1992. Thought and Language. Routledge. London.

Mpemba, E.B. and Osborne, D.G. 1979. The Mpemba Effect. Physics Education **14**: 410 -413.

Nangu, N.C. 1994. How can we be expected to learn science in English? In M.J. Glencross (Ed.) Proceedings of the Second Annual meeting of the Southern African Association for Research in Mathematics and Science Education. University of Durban- Westville, Durban, South Africa. 1994. 292 - 299.

Nelkon, M. 1979. C.S.E. Physics. Hart - Davis Educational. St. Albans, Hertfordshire.

Nkopodi, N. and Rutherford, M 1993. A poster presented at the Southern African Association for Research in Mathematics and Science Education Conference, Grahamstown 1993.

Nkopodi, N. and Rutherford, M. 1994. Some data collection methods used to identify conceptual and language difficulties. In M.J. Glencross (Ed.) Proceedings of the Second Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Durban-Westville, Durban, South Africa. 1994 . 300 -313.

Ogborn, J. 1985. Understanding students' understandings: An example from dynamics. European Journal of Science Education. Vol. 7 No. 2 141 - 150.

Ogunniyi, M.B. 1988. Adapting Western Science to Traditional Culture. International Journal of Science Education **10**: (1) 1 - 9.

Ogunniyi, M.B. 1995. World View Hypothesis and Research in Science Education. In A. Hendricks (Ed.) Proceedings of the Third Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Cape Town.

Opalko, J. 1991. Cross-Cultural Physics. The Physics Teacher. Volume **29**: (3) 155 - 158

Osborne, R.J. and Gilbert, J.K. 1980. A technique for exploring students' view of the world. Physics Education **15**: 376 - 379.

Osborne, R.J.; Bell, B.F. and Gilbert, J.K. 1983. Science Teaching and children's view of the World. European Journal of Science Education **5** : 1 - 4.

Osborne, R.J. and Freyberg, 1985. Roles for the Science Teacher. In Osborne, R and Freyberg, P. (Ed.) Learning in Science. Heinemann New Hampshire.

Pines, A.L. 1985. Toward a Taxonomy of Conceptual Relations and the Implications for the Evaluation of Cognitive Structures. In L.H.T. West and A.L. Pines, Cognitive Structure and Conceptual Change. Academic Press, Inc. London 101 - 115.

Pintrich, P.R.; Marx, R.W. and Boyle, R. 1993. Beyond cold conceptual change: The role of motivation beliefs and classroom contextual factors in the process of Conceptual Change. Review of Educational Research **63**: (2) 167 - 199.

Posner, G.J.; Strike, K.A.; Hewson, P.W. and Gertzog, W.A. (1982). Accommodation of a Scientific Concept: towards a theory of Conceptual Change. Science Education **66**: 221-227.

Redish, E.F. 1994. Implications of Cognitive Studies for Teaching Physics. American Journal of Physics **62**: (9). 796 - 803.

Redish, E.F. 1993. What Can a Physics Teacher Do with a Computer? An invited talk at Robert Resnick Symposium RPI, Troy New York.

Rollnick, M.S. 1988. Mother tongue, Intellectual environment and Conceptual Change strategies in the learning of Science Concepts in Swaziland. Unpublished doctoral thesis. University of Witwatersrand, Johannesburg.

Rutherford, M. 1993. Making Scientific Language accessible to Science Learners. In V. Reddy (Ed.) Proceedings of the First Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. Centre of the Advancement of Science and Mathematics Education, University of Natal, Durban. 1993. 280-288.

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. International Journal of Science Education **12**: (4) 443 - 456.

Sadanand, N. and Kess, J. 1990. Concepts in Force and Motion. The Physics Teacher. November 1990. 530 -533.

Sanders, M. 1995. Useful Format for Questionnaires and Tests used in Educational Research. In A. Hendricks (Ed.) Proceedings of the Third Annual Meetings of the Southern African Association of Research in Mathematics and Science Education University of Cape Town. Cape Town.

Sanders, M. 1996. Improving the quality of Science Education Research by promoting the "Rival Hypothesis". In D Grayson (Ed.) Proceedings of the Fourth Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Natal, Pietermaritzburg.

Sanders, M. and Banda, G. 1995. Questioning the Validity of Research Instruments: An Essential Step in Educational Research. In A. Hendricks (Ed.) Proceedings of the Third Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Cape Town. Cape Town.

Sanders, M. and Sebego, S. 1996. Developing and using a research instrument to establish pupils' ideas about "sex education". In D. Grayson (Ed.) Proceedings of the Fourth Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. University of Natal , Pietermaritzburg.

Seepe, P.S. 1993. Misconceptions in Newtonian Dynamics held by South African College Students. In V. Reddy (Ed.) Proceedings of the First Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. Centre of the Advancement of Science and Mathematics Education. University of Natal, Durban. 1993. 288 - 300.

Sequeira, M. and Leite, L. 1991. Alternative Conceptions and History of Science in Physics Teacher Education. Science Education **75**: (1) 45 - 56.

Seretlo, J.R. 1973. Some factors influencing the African attitude to science and his performance therein. An inaugural lecture given in the University of Fort Hare on the 8th June 1973.

Sidhu, K. S. 1995. Methodology of Research in Education. Sterling Publishers Private, Ltd New Delhi - 110016.

Strike, K.A. and Posner, G.J. 1985. A conceptual change view of learning and understanding. In L.H.T. West and A.L. Pines (Ed.) Cognitive Structure and Conceptual Change. Academic Press. London. 211 - 230.

Thijs, G.D. 1992. Evaluation if an Introductory Course of "Force" Considering Students' Preconceptions. Science Education **76** (2): 155 - 174.

Thijs, G.D. and Van Den Berg, E. 1994. Cultural factors in the origin and remediation of alternative conceptions in physics. Science and Education. Kluwer Academic Publishers. 1 -32.

Tomasini, N.G. and Balandi, B.P. 1983. Pupils' Conceptions: Some implications for teacher training. International Summer Workshop: Research on Physics Education. La Londe les Maures, Paris. France. 479 - 488.

Trowbridge, D.E. and McDermott, L.C. 1980. Investigation of student understanding of the Concept of Velocity in one Dimension. American Journal of Physics. **48** : (12). 1020-1028.

Trowbridge, D.E. and McDermott, L.C. 1981. Investigation of student understanding of the Concept of Acceleration in one Dimension. Amercan Journal of Physics. **49** : (3) 242-253.

Touger, J.S. (1991). When words fail us. The Physics Teacher. **29**: (2) February 1991, 90 - 95.

Van Aswegen, H. J. (1990). History of South Africa to 1854. Van Schaik. Pretoria.

Van Heuvelen, A. 1991. Learning to think like a physicist. A review of research-based instructional strategies. American Journal of Physics **59** : (10). 891 - 897.

Van Hise, Y.A. 1988. Student Misconceptions in Mechanics: An International Problem? The Physics Teacher November 1988.

Viennot, L. 1979. Spontaneous learning in elementary dynamics. European Journal of Science Education **1**: (2) 205 - 221.

Von Glaserfeld, E. 1991. A constructivist's view of learning and teaching. In R. Duit, F.Goldberg and H Niedderer (Eds). Research in Physics Learning: Theoretical Issues and Emperical Studies. Proceedings of anInternational Workshop held at the University of Bremen.

Vygotsky, L. S. 1962. Thought and Language. E. Hanfmann & G. Vaker (translaters) Cambridge M A. M I T Press.

Vygotsky, L. S. 1978. Interaction between Learning and Development. In M Cole, S Scriber, V John-Steiner and E Soberman (Eds): Mind in Society: Development of Higher Psycological Processes. Cambridge M A; Harvard University Press.

Watts, D.M. 1983. A study of school children alternative frame works of the concept of force. European Journal of Science Education **5**: (2) 217 - 230.

Watts, D.M. and Zylbersztajn, A. 1981. A survey of some children about force. Physics Education **16**: 360 - 365.

White, B.Y. 1983. Sources of Difficulties in Understanding Newtonian Dynamics. Cognitive Science. **7**: 41 - 65.

White, R.T. 1988. Learning Science. Blackwell Publishers. Oxford.

Whorf, B.E. 1973. Language, Thought and Reality. Massachusets Institute of Technology Press. Cambridge. Massachusetts.

Wittrock, M.C. 1985. Learning Science by generating new conceptions from old ideas. In West, L.H.T. and Pines, A.L.: Cognitive Structure and Conceptual Change. Academic Press, Inc. London. 259 - 266.

Zhaoyao, M. 1993. Difficulties in teaching and learning mechanics: a consideration of three problems. Physics Education **28**: 371 - 375.

APPENDICES

APPENDIX 1

MATRIC RESULTS

APPENDIX 2

THICK STRIPE ALONG THE MOUNTAINS

SOTHO GROUP ARE IN THE WEST OF THE STRIPE

NGUNI GROUP ARE IN THE EAST OF THE STRIPE

APPENDIX 3

SUNDAY TIMES OF THE 9TH APRIL 1995

LIGHTNING WITCHCRAFT REPORT

APPENDIX 4

TASK 1: MOSHOESHOE'S WARS (THREE VERSIONS) AND

THABA BOSIU MAP

APPENDIX 5

TASK TWO: QUIZ QUESTION

APPENDIX 6

TASK THREE: QUIZ TWO

APPENDIX 7

BOOK PAGE: Nelkon, N. 1975. CSE Physics

APPENDIX 8

PICTORIAL MULTIPLE CHOICE

APPENDIX 9

Teacher Mk interviewed

APPENDIX 10

Teacher Paul interviewed

APPENDIX 11

Mavlyn interviewed

APPENDIX 12

Binding Energy

APPENDIX 13

SELECTION SCALE UNIVERSITY OF NATAL

APPENDIX 14

Boitjhorosong Interview

APPENDIX 15

Uniqwa Interview

APPENDIX 16

Tshiya College of Education Interview

APPENDIX 17

Teacher Ma interviewed

APPENDIX 18

Teacher Mm interviewed

APPENDIX 19

Teacher Nts interviewed

APPENDIX 20

Investigator's life story in studies in physics

APPENDIX 21

Question 4 responses and translations from African subjects of the Control group

APPENDIX 22

Teacher Bofelo interviewed

APPENDIX 23

Teacher Khalipha interviewed

APPENDIX 24

Steve and Mike interviewed

APPENDIX 25

Mr Q interviewed

ANALYSIS OF STD 10 PHYSICAL SCIENCE RESULTS

1992 VS 1991

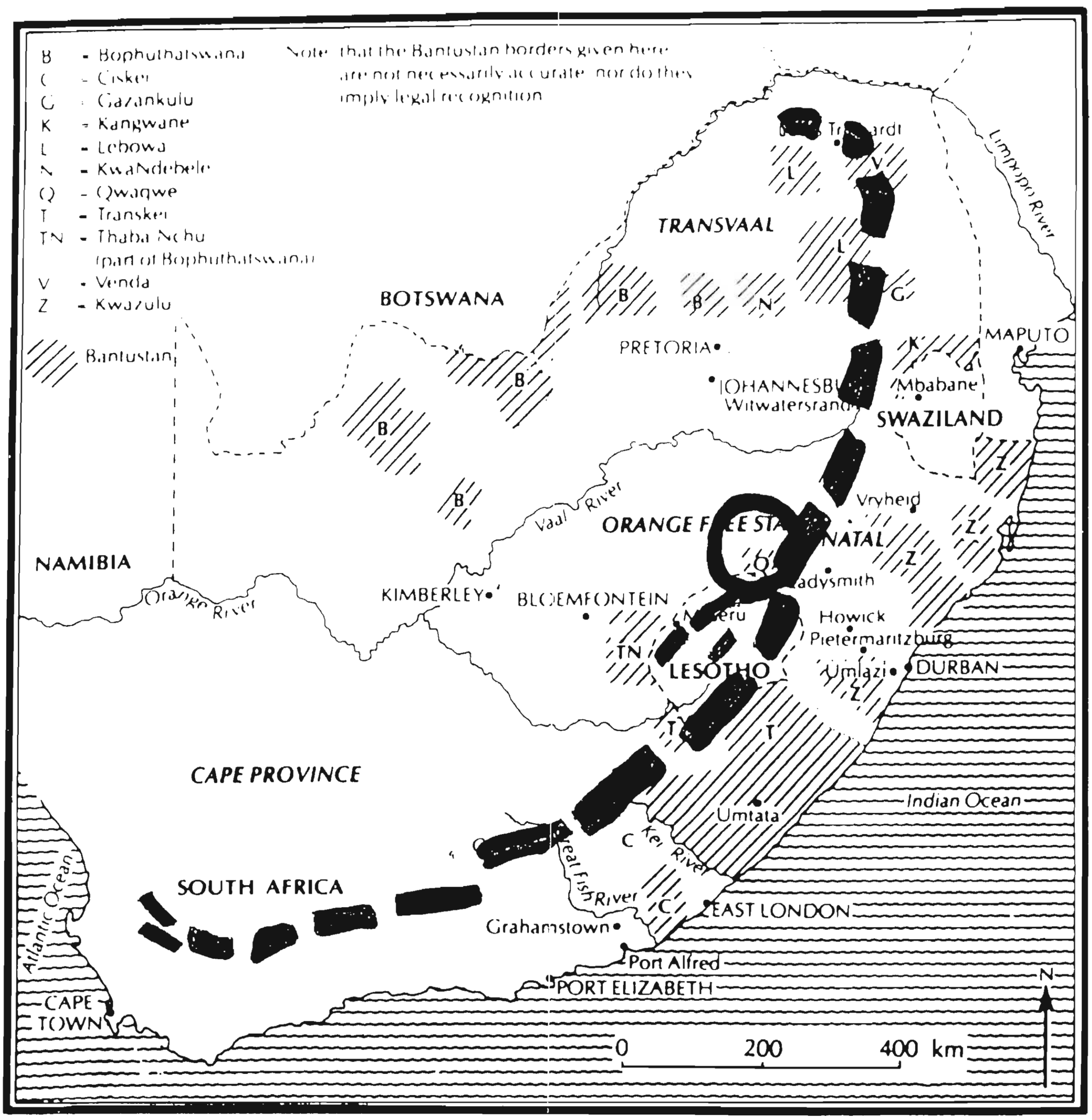
CENTRE	CIRCUIT	YEAR	A	B	C	D	E	F	FF	G	GG	H	X	WROTE	FAIL	PASS	%PASS	TEACHER AND QUALIFICA-TION
BEACON	WEST	1992 1991	-	-	-	3	2	5	-	-	-	-	-	10	-	10	100	(BSc)
TLHORONG	CENTRAL	1992 1991	-	-	-	-	2	4	-	-	-	-	-	7	-	7	100	(STD)
NKGOBISO	CENTRAL	1992 1991	- -	- -	- -	- 1	11 6	6 8	- -	- 4	2 -	- 3	1 -	19 22	2 7	17 15	89,5 68,2	(BSc Ed) (BSc Ed)
LEKGULO	WEST	1992 1992	- -	- 1	- -	2 4	15 10	17 14	- 2	- 11	5 -	1 1	2 -	40 43	6 14	34 29	85 67,4	(STD) (BSc + B.Ed)
TSHOLO	SOUTH	1992 1991	- -	1 -	1 -	4 2	6 8	25 10	- -	- 19	8 -	1 14	2 3	46 53	9 33	37 20	80,4 37,7	(STD 10 + PTC) (STD 10 + PTC)
SERGALI	SOUTH	1992 1991	- -	- -	- -	1 -	1 2	12 2	- 2	- 8	2 -	3 4	- -	19 18	5 24	14 4	73,7 22,2	(P TD) (P TD)
THALABODIBA	CENTRAL	1992 1991	- -	- -	- 2	- 2	8 5	17 10	- 3	- 16	7 -	2 6	2 2	34 44	9 25	25 19	73,5 43,2	(BSc) (BSc)
MAMPOI	CENTRAL	1992 1991	- -	- 1	1 2	1 8	21 22	17 15	- 3	- 18	5 -	11 7	1 -	55 76	15 28	40 48	72,7 63,2	(BSc) (S T.D)
TSEKI	WEST	1992 1991	- -	- 1	1 -	3 1	25 11	21 13	- -	- 13	13 -	10 11	3 -	73 51	23 25	50 26	68,5 51,0	(BSc + B.Ed) (BA + JSTC)
THOKOANA	NORTH	1992 1991	- -	- -	- -	3 2	3 5	19 2	- 3	- 15	9 -	5 20	3 -	39 47	14 38	25 9	64,1 19,1	(S E.D) (S E.D)
PHOFUNG	SOUTH	1992 1991	- -	- -	- -	1 -	2 2	9 2	- 1	- 13	2 -	5 6	- -	19 24	7 20	12 4	63,2 16,7	(STD 10)
MAKHABANE	WEST	1992 1991	- -	- -	- -	- -	3 1	11 2	- -	- 9	5 -	4 21	- -	23 33	9 30	14 3	60,9 9,1	(STD 10 + PTC) (BSc)
MAANANKWE	SOUTH	1992 1991	- -	- -	1 2	1 2	5 2	6 6	- -	- 6	3 -	6 18	1 3	22 36	9 24	13 12	59.1 33,3	(STD 10 + PTC) (STD 10 + PTC)
KOALI	WEST	1992 1991	- -	- -	- -	2 1	5 4	15 8	- 21	- 24	12 -	5 24	! 2	39 58	17 46	22 13	56,4 22,4	(BSc Ed) (BSc Ed)
MOHATO	WEST	1992 1991	- -	- -	1 2	1 -	11 4	15 12	- -	- 6	6 -	9 21	1 2	53 45	25 27	28 18	52,8 40	(BSc Ed) (BSc Ed.)
REAHOLA	NORTH	1992 1991	- -	- -	- -	- 2	7 3	13 7	- 2	- 6	5 -	13 10	1 -	38 30	18 18	20 12	52,6 40	(S T.D.) (S T.D.)

APPENDIX I
MATRIC RESULTS

CENTRE	CIRCUIT	YEAR	A	B	C	D	E	F	FF	G	GG	H	X	WROTE	FAIL	PASS	%PASS	TEACHER AND QUALIFICA-TION
MOHALDITWE	NORTH	1992	-	-	1	-	3	17	-	-	12	8	-	41	20	21	51,2	(S T D.)
		1991	-	-	-	-	1	6	1	6	-	16	-	30	23	7	23,3	(S T D.)
METSIMATSHO	SOUTH	1992	-	-	-	1	11	11	-	-	7	15	2	45	22	23	51,1	(STD 10 + PTC)
		1991	-	-	-	-	1	5	1	8	-	13	-	28	22	6	21,4	(STD 10 + PTC)
KGOLATHUTO	NORTH	1992	-	-	-	3	9	22	-	-	15	18	3	67	33	34	50,7	(S T D.)
		1991	-	-	-	-	1	5	-	12	-	15	-	33	27	6	18,2	(S T D.)
MANTHATISI	NORTH	1992	-	-	-	2	2	19	-	-	12	13	2	48	25	23	47,9	(BSc Ed.)
		1991	-	-	-	-	1	5	-	13	-	30	6	49	43	6	12,2	(BSc Ed.)
MOTEKA	NORTH	1992	-	-	-	1	2	23	-	-	15	14	1	55	29	26	47,3	(S T D.)
		1991	-	-	-	-	8	9	3	20	-	19	-	59	42	17	28,8	(B A + H E D.)
MAKABELANE	NORTH	1992	-	-	-	-	9	20	-	-	15	18	-	62	33	29	46,8	(BSc Ed.)
		1991	-	-	-	2	14	-	-	22	-	31	4	69	53	16	23,2	(BSc Ed.)
RANTSANE	NORTH	1992	-	-	-	-	2	17	-	-	10	13	-	42	23	19	45,2	(STD 10 + S E C.)
THAHANESO	CENTRAL	1992	-	-	-	2	10	12	-	-	17	18	-	59	35	24	40,7	(BSc)
		1991	-	-	-	3	15	21	2	14	-	19	-	74	35	39	52,7	(BSc)
DIKWENA	CENTRAL	1992	-	-	-	-	4	13	-	-	14	17	2	48	31	17	35,4	(BSc)
		1991	-	-	1	1	3	6	-	13	-	18	-	42	31	11	26,2	(BSc)
MOOKODI	SOUTH	1992	-	-	-	-	8	28	-	-	17	54	2	107	71	36	33,6	(STD 10 + PTC)
		1991	-	-	-	-	7	10	-	30	-	29	2	86	69	17	19,8	(STD 10 + PTC)
SEKGUTLONG	WEST	1992	-	-	-	-	2	10	-	-	5	25	1	42	30	12	28,6	(BSc + PTC)
		1991	-	-	-	-	-	4	-	10	-	35	1	49	45	4	8,2	(BSc + PTC)
SELELEKELA	NORTH	1992	-	-	-	-	13	9	-	-	17	51	3	90	68	22	24,4	(BSc Ed.)
		1991	-	-	1	1	5	14	-	18	-	41	-	80	59	21	26,3	(BSc Ed.)
TSEBO	CENTRAL	1992	-	-	-	-	13	15	-	-	29	115	4	172	144	28	16,3	Tsotetsi
		1991	-	-	-	-	4	14	1	24	-	29	3	72	54	18	25	Tsotetsi
SEBABATSO	WEST	1992	-	-	-	-	5	10	-	-	24	65	1	104	89	15	14,4	(STD)
		1991	-	-	-	-	5	4	-	17	-	46	4	72	63	9	12,5	(BSc Hons.)
	TOTAL	1992	-	1	6	32	220	438	-	-	293	519	39	1518	821	697	45,9	
		1991	-	3	10	30	156	214	24	372	-	517	32	1323	914	409	30,9	

APPENDIX 2

THICK STRIPE ALONG THE MOUNTAINS
SOTHO GROUP ARE IN THE WEST OF THE STRIPE
NGUNI GROUP ARE IN THE EAST OF THE STRIPE



See Page

APPENDIX 3
SUNDAY TIMES OF THE 9TH APRIL 1995
LIGHTNING WITCHCRAFT REPORT

Plan to uproot belief in witches

By VICTOR KHUPISO

THE Azanian People's Organisation in Lebowa is to launch a campaign against witchcraft.

Last month alone 12 people were set alight in one village after they were accused of being witches.

The Rev Kgotsupo Liputu of Azapo's central committee is responsible for the campaign.

He said Azapo would launch workshops in the villages: "We want to stop this menace and people need to be informed.

"When it starts raining people just run away because they don't know when the lightning will strike and who will be pointed out as the culprit," Mr Liputu added.

He said unemployed youths were forcing villagers to pay for *inyangas*, who identified "witches responsible for deaths".

"Innocent people are pointed out as responsible, then the whole family is wiped out.

"Sanity must prevail and we feel it is our responsibility to remedy the situation.

"There is no future for a nation that believes anything that went wrong is caused by witchcraft."

Kgomo police spokesman Major Ernest Setati said witch-hunting had created a serious problem in the area.

"There were cases last year, but the latest seemed to be worse within this short space ...However, we are doing our best to control the situation."

APPENDIX 4
TASK ONE
MOSHOESHOE'S WARS

Surname :	National Group:
Name :	Std 10 School :
Mother tongue:	Province :

King Moshoeshoe and his Basotho people occupied the vast plains of the now Free State, living on crop and stock farming. When war was imminent, he would retreat to Thaba Bosiu across the Mohokare (Caledon) River. This Thaba Bosiu is a Table-like mountain with only one narrow climbable path to its top. If the enemy pursued Moshoeshoe up the mountain, he and his people would roll down some boulders from the top of the mountain which were previously gathered specifically during the peace time for this purpose.

One boulder, colliding with several other boulders, would rain on the enemy who by then would almost be at the top of the mountain. This action killed most of the enemy, leaving only a very few who could outrun the lazier ones in the race to the foot of the mountain. When the battle was over, men would roll boulders back up to the mountain top, ready for the next battle. If boys tried to roll boulders up, the boulders would not move, or would move up a short distance and roll back to where they have been.

Note: 1 Give your answers in (1) your own language
(2) English
2 Answer the questions in sequence; do not cross out anything that you have already written
3 Do not use the words: strong, strength, stamina, mighty
4 Give as many answers as possible that are appropriate

Questions

1 As boulders rolled down, which quantity or quantities did they gained?
2 Which quantity or quantities did the boulders fall down on the enemy with?
3 Each boulder, colliding with a neighbouring boulder, which quantity was given?
4 To kill a man a boulder must fall on him with much .....?
5 Men rolled the boulders up faster than boys, because .....?
6 Boys could not even move the boulders because .....?
7 If A outruns B, what does A do that B fails to do?
8 X and Y are rolling identical boulders up. X arrives at the top ten minutes before Y. Why?
9 Boulders P and Q leave the mountain top at the same time. After five seconds P is ten meters away while Q is twenty meters away, both being equal in all respects. Describe their movement clearly outlining the difference.
10 Translate the following Biblical verse into your own language: ".....who gives us strength with His mighty power,..... far above all authority, all parol might against the force of evil by the right to be His children".

APPENDIX 4
TASK ONE
MOSHOESHOE'S WARS

Surname :
Name :
Mother tongue:

National Group:
Std 10 School :
Province :

King Moshoeshoe and his Basotho people occupied the vast plains of the now Free State, living on crop and stock farming. When war was imminent, he would retreat to Thaba Bosiu across the Mohokare (Caledon) River. This Thaba Bosiu is a Table-like mountain with only one narrow climbable path to its top. If the enemy pursued Moshoeshoe up the mountain, he and his people would roll down some boulders from the top of the mountain which were previously gathered specifically during the peace time for this purpose.

One boulder, colliding with several other boulders, would rain on the enemy who by then would almost be at the top of the mountain. This action killed most of the enemy, leaving only a very few who could outrun the lazier ones in the race to the foot of the mountain. When the battle was over, men would roll boulders back up to the mountain top, ready for the next battle. If boys tried to roll boulders up, the boulders would not move, or would move up a short distance and roll back to where they have been.

Note:
1 Give your answers in (1) your own language
(2) English
2 Answer the questions in sequence; do not cross out anything that you have already written
3 Do not use the words: strong, strength, stamina, mighty
4 Give as many answers as possible that are appropriate

Questions

1 As boulders rolled down, which quantity or quantities did they gained?
2 Which quantity or quantities did the boulders fall down on the enemy with?
3 Each boulder, colliding with a neighbouring boulder, which which quantity was given?
4 To kill a man a boulder must fall on him with much .....?
5 Men rolled the boulders up faster than boys, because .....?
6 Boys could not even move the boulders because .....?
7 If A outruns B, what does A do that B fails to do?
8 X and Y are rolling identical boulders up. X arrives at the top ten minutes before Y . Why?
9 Boulders P and Q leave the mountain top at the same time. After five seconds P is ten meters away while Q is twenty meters away,, both being equal in all respects. Describe their movement clearly outlining the difference.
10 Translate the following Biblical verse into your own language: ".....who gives us strength with His mighty power,..... far above all authority, all power,all might against the force of evil by the right to be His children".

REPHRASED
REWORDED B.

TASK ONE

Surname :
First Name :
Language spoken home:
Other languages:
(speaking, reading? writing?)

Date:
Std 10 School :
Province :
Physics Course: 110A 110B 110D 110S
(circle or include it)

King Moshoeshoe and his Basotho people occupied the vast plains of what is now the Free State, living on crop and stock farming. When war was imminent, he would retreat to Thaba Bosiu across the Mohokare (Caledon) River. This Thaba Bosiu is a Table-like mountain with only one narrow climbable path to its top. If the enemy pursued Moshoeshoe up the mountain, he and his people would roll down some boulders from the top of the mountain which were previously gathered specifically during peace time for this purpose.

One boulder, colliding with several other boulders, would rain on the enemy who by then would almost be at the top of the mountain. This action killed most of the enemy, leaving only a very few who could outrun the lazier ones in the race to the foot of the mountain. When the battle was over, men would roll boulders back up to the mountain top, ready for the next battle. If boys tried to roll some boulders up, the boulders would not even move, or would move up a short distance and roll back to where they have been.

For each question:

1 Give your answers in (a) your own language (if different from English)
(b) English

2 Do not use the words: strong, strength, stamina, mighty

3 Give as many answers as possible that are appropriate

Questions (use the back of the page if space supplied is not enough for your answer)

1 As boulders rolled down, which quantity or quantities did they gained?
(a)
(b)

2 When a boulder collides with a neighbouring boulder, which quantity or quantities does it impart to its neighbour?
(a)
(b)

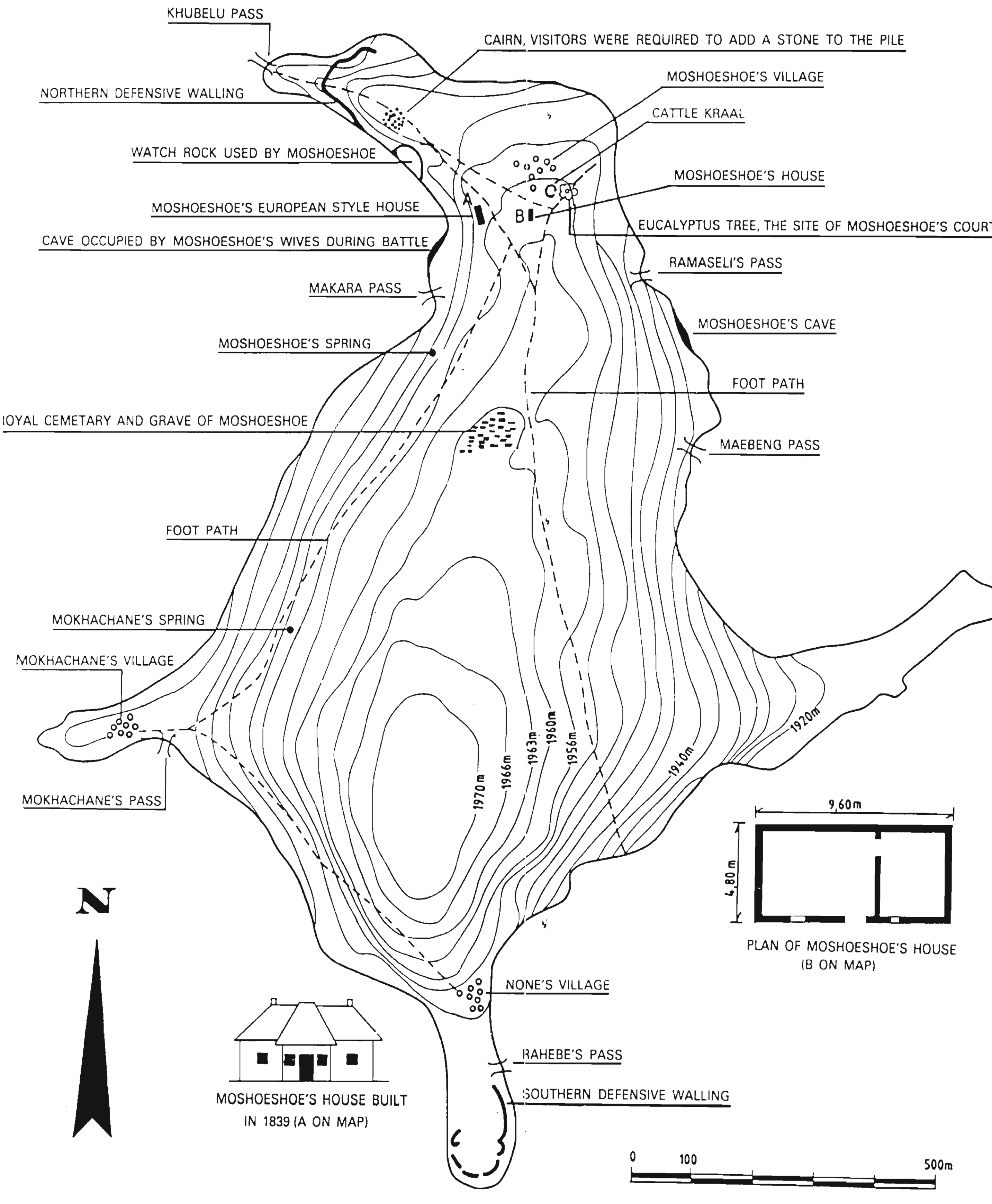
3 Some falling boulders can kill a man. For such a boulder to kill a man it must have a large amount of ...(a)....., ..(b)...(fill in the appropriate quantity in your language and in English)

4 Some small boys could not even move the boulders; in terms of mechanics concepts, in what ways are the boys different from men?
(a)
(b)

5 Man X and man Y are rolling identical boulders up the mountain. Man X arrives at the top ten minutes before man Y. Describe the differences between man X rolling the boulder and man Y rolling the boulder in terms of as many mechanics concepts as you think are relevent.

LESOTHO

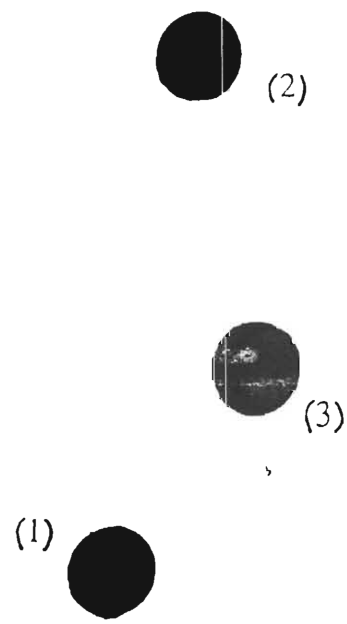
PRESERVATION AND PRESENTATION OF THABA BOSIU, THE NATIONAL MONUMENT



APPENDIX 5
TASK TWO
QUIZ QUESTION

Name:

Class:



A ball is thrown up in the air, leaving the thrower's hand, going almost vertically upwards; it reaches the highest position; it then turns down to the ground. There are three positions of the ball marked:

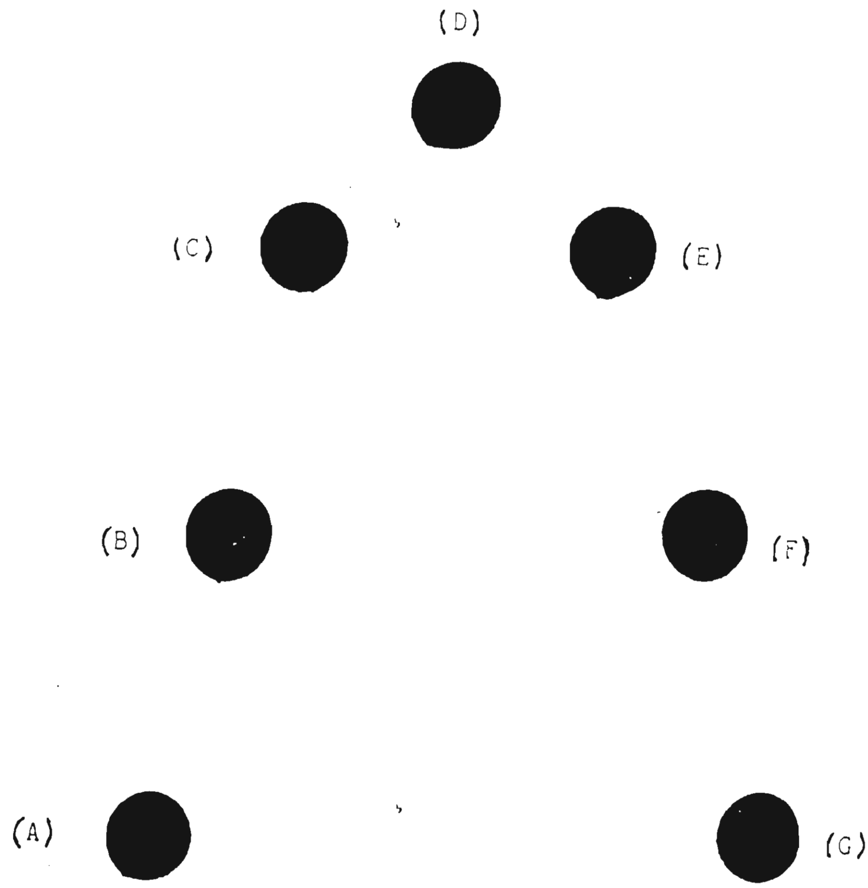
(1) going up (2) highest position (3) going down

Draw arrows to indicate all forces on the ball at each position; the length of each arrow must indicate the size of the force; and each force must be properly labelled.

APPENDIX 6
TASK THREE
QUIZ TWO

Name:

Class:



Give answers in your own language, mentioning also the needed item in your answer.

At which of the labelled positions, if any, is the speed of the ball the same?

At which positions is the velocity the same?

At which positions is the acceleration the same?

At which position is the force the same?

BOOK PAGE: Nelkon, N. 1975. CSE Physics

A heavy bob, swinging to and fro at the end of a pendulum, shows similar changes in potential and kinetic energy. If the horizontal through the lowest point B of the swing is taken as a reference 'zero' of potential energy, then at the top of the swing A the bob has maximum potential energy (P.E.) but zero kinetic energy (K.E.), Fig. 7.29. At the middle B, the kinetic energy becomes a maximum and the potential energy is correspondingly zero.

Power

Two boys of the same weight each set out from the bottom of a hill to reach the top walking at a steady speed. One, X, is athletic and strong. The other, Y, is the opposite type, not athletic and weak. X can reach the top in a much shorter time than Y. Walking steadily,

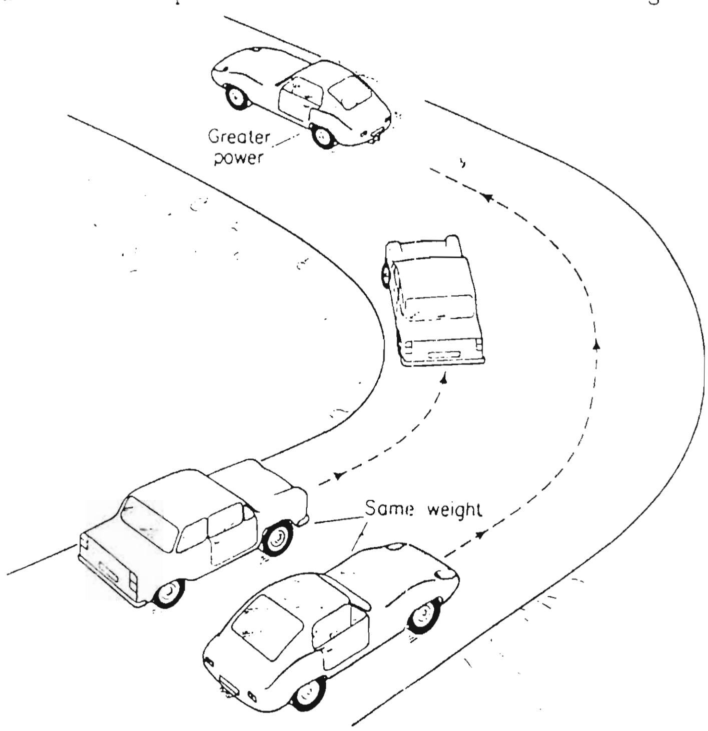


Fig. 7.30 Power

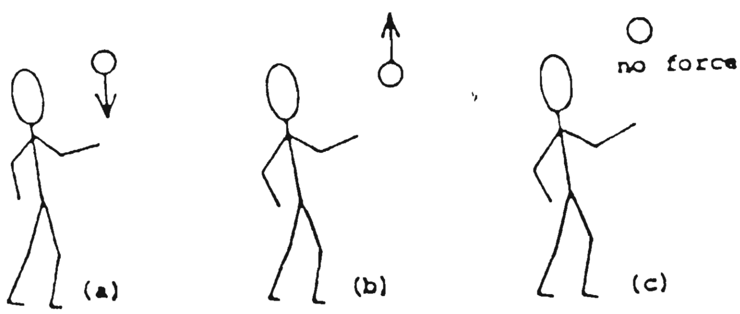
each has overcome the same frictional forces at the ground, and each has raised the same weight through the same height. Consequently each has done the same amount of work. X, however, has done it in a shorter time than Y. We say that X has a greater *power* than Y. In the same way, a large engine can work faster than a small engine of the same kind and is said to have a greater power. In Fig. 7.30, for example, the dark car is climbing a hill at a faster steady speed than the light car,

APPENDIX 8

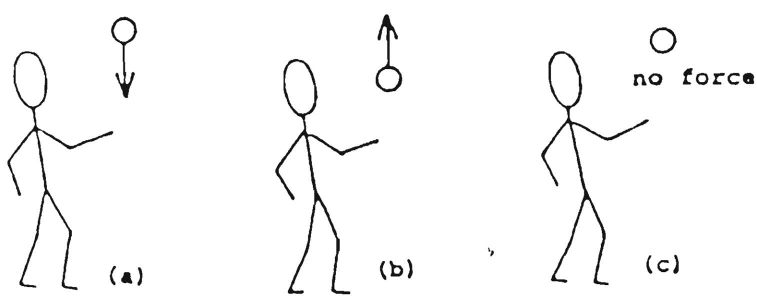
A person throws a tennis ball straight up into the air just a small way.

The questions are about the total <u>force</u> on the ball.

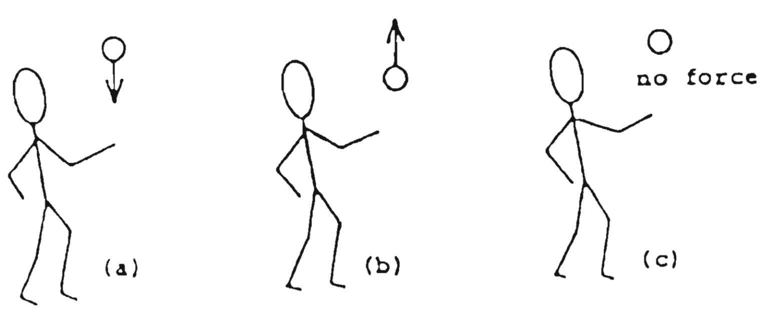
<u>If the ball is on the way up</u>, then the <u>force</u> on the ball is shown by which arrow?



<u>If the ball is just at the top of its flight</u>, then the <u>force</u> on the ball is shown by which arrow?



<u>If the ball is on the way down</u>, then the <u>force</u> on the ball is shown by which arrow?



APPENDIX 9

Teacher Mk interviewed:

Teacher Mk has been teaching physical science in Sebabatso, a Senior Secondary in Qwa Qwa, for six years. He was trained as a teacher in Tshiya College of Education. The investigator and teacher Mk know each other well; the investigator sent a message to teacher Mk a week prior to the date of interview where he was requested to be interviewed about what he teaches students; It was a pleasure to teacher Mk to participate in such an interview as he indicated after it.

I :My name is Cable Moji, my home is Namahadi; I have been lecturing Uniqwa physics for some ten years. So all the students that pass through your hands to come to university, they come to me; so I have to sort out the problem these students present at the university in a research study. I wanted to find out if these are the problems of the children, they don't understand, or what causes their poor performance. There is a story along with my inquiry after which there are about six or seven over which we will be talking together for about twenty minutes; we can look at the story:

The story of Moshoeshoe's wars was read

Let us try to avoid usually go well in physics such as strong, strength, stamina, might and mighty. The first question is: As boulders rolled down, which quantity or quantities did they gain?

Mk :Ok, may I ask a question? Is this related to the story you've just read?

I :Of course, yes, but now you are going to apply physics in it; it is not that you will get the answer directly from it. [He nodded]. But now we are trying to talk physics because in the books we read about roller coasters, the bunji jumps and the merry-go-rounds which the students in Sebabatso do not know about but would know about a boulder rolling down the mountain.

Mk :As it is rolling down it is gaining momentum.

I :Ok, do you think momentum and something else?

Mk :And potential energy actually.

I :Ok, you say potential energy as well; is there anything else or they are the only two?

Mk :Yea, I am satisfied.

I :What would you call them in your own language? Remember we must also know them in our own language.

Mk :[He frowned] I think... momentum in my own language [thinking for a long time]...

I :There is no word for that?

Mk :Yea, I think so, not unless I explain it.

I :How would you explain it?

Mk :For instance, maybe I should explain it is a product of mass and velocity...

I :Fine, explain it in your own language, Mr Mk, ke eng ka Sesotho momentum (what is it in Sesotho, this momentum)?

Mk :Ae, I cannot explain.

I :Potential energy yona (what about potential energy)?

Mk :[Long quietness] Ke energy e bolokilweng (It is a stored energy).

I :Energy ha ra na lentswe la Sesotho ho yona (have we not got Sesotho word for energy)?

Mk :Energy? Ke matla! (Energy, is matla).

I :Ok, matla a bolokilweng; let us go to the second question: When the boulder goes down, it collides with the stationary other boulders that are nearby; which quantity does this rolling boulder impart to the standing one down the mountain?

Mk :It imparts momentum.

I :Ok, momentum. Is it only momentum?

Mk :It imparts energy as well.

I :Ok, anything else?

Mk :And then the force.

I :Ok, it imparts the force, anything else?

Mk :[Quietness]

I :Alright, Mr Mk, what are these things, what is momentum, energy and force, what are they ka puo ya heno (what are they in your language)?

Mk :Energy ke itse ke matla (energy I said is matla).

I :Ok, can you give a word for kinetic energy?

Mk :Ke matla a... (It is matla for...)..........[quietness].

I :What about force?

Mk :Ke hula - sututsa. Ke ho hula kapa ho sututsa (it is to pull or to push).

I :Alright let's go to the third one: some falling boulders can kill a man. For such a boulder to kill a man it must have a large amount of ....(some quantity). We must give the appropriate quantity even in our language.

Mk :It must be a large amount of force.

I :So what is force in Sesotho?

Mk :E tlamehile ho ba matla a maholo (It must surely be large matla).

I :Ok, are you now dodging the hula - sututsa because remember you said matla ke (is) energy, now matla a maholo, do you want to add anything else?

Mk :No. [laughter].

I :We go to the fourth question. Some boys could not even move boulders. In terms of the mechanics concepts, in what ways were the boys different from men?

Mk :I think it was in terms of the energy that they have and of course the force that they are applying is not the same as ... [quietness].

I :You say energy, what kind of energy... and anything else?

Mk :I can also say power that they are using.

I :You say the energy and the power?

Mk :Yea, I want to combine the two. The power they use as connected to the energy.

I :Where does the power come from? You said they are using power!

Mk :I can say they use it from their muscle.

I :You haven't said energy and power in your language.

Mk :Energy e ntse e le matla, power [thinking] nkare keng? bokgoni (energy is still matla, power, what can I say? bokgoni).

I :Let us go to the last question in this task. Man X and man Y are rolling identical boulders up the mountain. Man X arrives ten minutes before man Y at the top of the mountain. Describe the difference between man X and man Y in terms of mechanics concepts.

Mk :I would also talk about energy or power.

I :Is it energy or power or both?

Mk :Both! power and energy.

I :What about power and energy in your language?

Mk : Power is bokgoni and energy is matla.

I :Now let us compare the Sesotho word you have given for power and the definition of power. How do you define power?

Mk :Power is the rate of doing work.

I :That is how quick you are doing work; but bokgoni tells us something ...does it imply that I can do it?

Mk :No it doesn't imply. If I want to explain power in Sesotho, I wouldn't use bokgoni.

I :Can I ask you the last one? If a ball thrown upwards, leaves the hand and goes up [Mk is shown a drawing where positions are indicated], what forces act on the ball at position 1, neglecting the air resistance?

Mk :We've got the gravitational force, and the force which is applied by the hand.

I :Even though the hand is no more there in touch of it?

Mk :Ok, only gravitational force.

I :So as it is going up, only gravitational force?

Mk :Yea.

I :At position 2?

Mk :Only the gravitational force.

I :At position 3?

Mk :Only the gravitational force.

I :Thank you, Mr Mk that you availed yourself for this interview.

APPENDIX 10

Teacher Paul interviewed

Teacher Paul is presently a subject adviser in the Free State Highlands region. He taught physical science for sixteen years in senior secondary schools such as Thokwana and Sekgutlong. He has a B.A. degree with mathematics up to the second year. He offered himself for interview after he understood what the investigator was studying. He appeared a concerned teacher in that he used to see his students also on Saturdays for extra lessons while he was still teaching.

The investigator explained to teacher Paul about the two tasks, that Moshoeshoe's wars was originally meant for the students from the remote South Africa who have not seen most of the items the textbooks refer to, such as roller coasters and bunji jumps. He was told that the aim was to discover if the mechanics concepts could also be identified correctly if seen from the boulders rolling down from the mountain.

Moshoeshoe's wars was read

I :As these boulders rolled down, what did they gain?

Paul :Velocity - that is all.

I :What is velocity in your language?

Paul :Ke lebelo (It is lebelo).

I :What is acceleration in your language?

Paul : [Pause, cough, laughter] Acceleration ha e yo haeso, empa e ka nna ya eba keketseho ya lebelo (we do not have acceleration, but it can be the increase of lebelo).

I :But do you think we realise it as acceleration?

Paul :E -e, re sheba lebelo feela (No we only look at lebelo alone).

I :We go to the second question: when boulders roll down, they collide with other neighbouring stationary boulders, what do the rolling boulders impart to the stationary boulders, what quantity do they impart?

Paul :Energy.

I :You don't want to classify that energy, which kind of energy?

Paul :Kinetic energy.

I :Kinetic energy and anything else, would there be any other quantity?

Paul :As far as I think, it is all.

I :What would you call kinetic energy in your language?

Paul :Ke matla... a ntho tse tsamayang (It is matla of the moving objects).

I :Let's go to the third question: some falling boulders can kill a man. For such a boulder to kill a man, it must fall on him with a large amount of some quantity, what would that quantity be?

Paul :Shall we say force?

I :Anything else, would it only be force?

Paul :Momentum.

I :Ok, you say force and momentum; what are force and momentum in your language?

Paul :Force ka Sesotho, e ka re e tla nne e be matla he (Force in Sesotho, it will probably still be matla then).

I :What is momentum in your language?

Paul :E ntse e le matla le yona (It is also matla too).

I :You must note now, you said energy is matla, you say force is matla and now you want to say momentum is matla as well.

Paul :E jwalokaha acceleration e le lebelo, velocity e le lebelo le speed e le lebelo (It is just as acceleration is lebelo, velocity is lebelo and speed is lebelo).

I :Ok, I am coming to the fourth question: what was the difference between boys and men since boys could not even move some boulders?

Paul :Boys did not have much, shall I call it power or energy, no energy as men do; so they would fail to exert enough force push the boulders up.

I :At first you said energy or power, now you say force....[interrupted].

Paul :I think you exert force to do the work, you need energy to enable you to exert force to do the work.

I :You need energy to exert force to do the work?

Paul :If you don't have energy, you will not be able to exert force. Without energy you are powerless.

I :Alright, what is the connection between power and energy, what is power in your language?

Paul :Ke matla (It is matla).

I: So are we counting four? Energy, force, momentum and power! Ke matla kaofela (all are matla's)?

Paul :Hantle! Ke matla kaofela (Exactly! all are matla's).

I :Alright, lets talk about the last one. Man X arrives at the top of the mountain ten minutes before man Y while both are rolling identical boulders up along identical paths. What is the difference between the two men, using mechanics concepts of course?

Paul :The one who is able to carry through this mass, is the one who has more power, who can endure the gravitational pull more than the other.

I :Let us be specific about mechanics concepts, how is X different from Y?

Paul :X has more speed than Y, it also means X accelerates more than Y.

I :It doesn't have anything to do with energy force and power?

Paul :It does, where I spoke about endurance to counteract the gravity, X endures more than Y, which means he is able to exert more force.

I :Thank you so much for availing yourself for this interview.

APPENDIX 11

MAVLYN INTERVIEWED

M is an Indian masters student in physics. He says his home language is English since Tamil, which was supposed to be his home language is much difficult and very people are still speaking it. The investigator was chatting freely with this fellow student of his at post graduate level in the Physics Department at the University of Natal. Pietermaritzburg.

I :If you throw a ball, what do you do if you want it to go much higher?

M :I would give it more force!

I :Give it more force?

M :Yes! more power would make go higher

I :More power?

(M noted that I was investigating something, he remembered that I am working on the amandla issue).

M : Ugh man! you give it more energy! Give it more amandla it will go higher.

There was a general laughter!

From the above conversation, can we ever be sure? Can we who have English as the second language trust .

APPENDIX 12

BINDING ENERGY

The investigator was lecturing Nuclear Physics to Uniqwa freshmen in the last term of 1994. One of the questions he posed to the students in the final examinations was to define Binding Energy. Since this was an examination question, there was no interview arranged.

12.1 Binding Energy - Results

The question in the examination was: Briefly define Binding Energy (It carried 1% mark of Physics One examination paper).

77 candidates wrote the examination. Some answered the question. The common majority answers are paraphrased as follows:

1 Binding energy is the energy holding atoms/molecules/electrons together
2 Binding energy is the strong force, like Coulomb force, keeping like charges together in the nucleus to overcome repulsion, causing mass defect.
3 Binding energy is the energy defect in the form of E = mc(2) necessary to keep nuclei intact in the atom
4 No answers

28% (22/77) of these first year physics students stated that this binding energy keeps molecules together, some said electrons together while some said atoms together.

25% (19/77) however, stated that Binding energy is the strong force keeping like charges together.

20% (15/77) answered that Binding energy is the energy keeping nucleons together

27% (21/77) did not answer for some reason

12.2 Binding Energy - Interpretation

The first 29% (22/77) apparently guessed the binding energy to be the entity that holds things together so that they should not fall apart. The incorrectness of the response is only that the subjects referred to molecules, atoms or electrons and not nucleons.

The second group of 25% (19/77) defined this energy in the responses that are interpreted by the investigator to have two separate but important backgrounds.

Background Coulomb stated that when like charges come together, there will be a force of repulsion; so then, to work against this force of repulsion, keeping these nuclear like charges together, is it not another force, opposite to Coulomb's force that is needed?

Background 2: When the two ends of a spring that is difficult to compress are pushed towards each other, students know that they need matla/amandla to do it. In the same fashion, charges that would otherwise scatter apart from repulsion need matla/amandla to keep them together. This matla/amandla could be the energy, the force or the power.

For this second group the investigator has an argument that the students do understand the theory of the binding energy; while due to language difficulties, from which the binding energy conceptualization will be obscured, the candidates will fail the question, yet conceptually the investigator believes they should be condoned.

The same condoning argument also is proposed for the Speed - Velocity - Acceleration conceptual terms. It would not be obvious to the student to differentiate one from another if from both observation and language they are not explicitly separated, hence the momentum will also not be easy to differentiate from force since both are products of mass and undifferentiated entities.

SELECTION SCALE OF THE UNIVERSITY OF NATAL

ACCESS TO UNIVERSITY

General Entrance Requirements

The basic requirement for admission to degree studies at University is a matriculation exemption certificate. Applicants need to be in possession of ONE of the following:

1. A Senior certificate with matriculation exemption
2. A Certificate of Conditional Exemption from the matriculation examination. Matriculants who did not obtain a full exemption and who wish to apply for a Conditional Exemption Certificate need to contact their school and Department of Education.
3. Applicants not qualifying for a conditional exemption certificate may apply for admission through an alternative selection programme, and on successful completion of the programme qualify for a Conditional Senate Exemption.
4. Mature Age Exemption: Applicants over the age of 23 may qualify for a conditional exemption certificate on grounds of mature age. Certain subject requirements apply and applicants must contact the admissions offices for more information. The University will apply to the Matriculation Board for an exemption certificate after the applicant has been selected into a faculty.
5. Foreign conditional exemption: Applicants in possession of non-South African school leaving certificates must apply to The Director, Matriculation Board, PO Box 3854, Pretoria 0001 for a Foreign Conditional Exemption Certificate.
6. For admission to certain diplomas the possession of a Senior Certificate (without exemption) is sufficient.

Faculty entrance requirements

Some faculties have laid down specific entrance requirements. These are listed under Faculty Information in this publication. Any applicant wishing to enter these faculties must meet these entrance requirements.

Selection procedures

Selection on matriculation point score:

Selection will commence as soon as the matriculation results are released and will continue until all available places have been allocated.

Students are admitted to the University on the basis of academic merit, which is assessed by converting matriculation symbols into a point score.

Once the examination results of all applicants are known, their scores are calculated and they are ranked in descending order of scores for their choice of degree/diploma and centre of study. Selection then takes place from the top down, until the number of applicants who may be accepted for that degree/diploma in that centre of study is reached. The score at which this is reached is known as the 'cut-off point', and this varies from one degree or diploma to the next.

Applicants below that total score are normally not selected. This total may change from year to year, depending on the number and quality of applications.

Although the University receives details of matriculation examination results direct from the Education Department, it is the responsibility of all **APPLICANTS** to ensure their preliminary statements of matriculation symbols reach the Admissions Office as soon as possible. Applicants must write their degree choice and student number on the statement.

Applicants with outstanding Standard 9, Matric June/Trial results may be provisionally selected on submission of a certified copy of the results.

Calculation of Matriculation Point Score:

The point score is calculated by matching each of the six b Matriculation subject symbols (other than Advanced Mathemati with the relevant value listed either under Higher Grade (HG) Standard Grade (SG) and then adding the scores to give the total

POINTS TABLE

SYMBOL	HIGHER GRADE	STANDARD GRADE
A	8	5
B	7	4
C	6	3
D	5	2
E	4	1
F	1	0

If a seventh subject was passed with a symbol of at least "E" on Hig Grade or "D" on Standard Grade, a bonus of two points will be adc to the score.

If a subject written on Higher Grade has been given a condoi Standard Grade pass, the points score is to be calculated using Standard Grade value.

EXAMPLE

SUBJECT	GRADE	SYMBOL	POINT
English	HG	B	7
Afrikaans (2nd Lang)	HG	C	6
Mathematics	HG	A	8
Physical Science	HG	D	5
History	SG	C	3
Geography	HG	E	4
	TOTAL POINTS		33

The cut-off or minimum points that prevailed in 1996 were follows:

Agriculture 32/30
Architecture..35
Humanities 29
Commerce/Economics and Management................32-35
Engineering (depending on specialisation) 38
Law (B.Proc) 30
Science (depending on specialisation and centre)....36/32
Social Science 29
B.Cur (Nursing) 30
Medicine..38

Alternative Selection and Admission Programm

Many prospective students have the potential to succee University, but come from school backgrounds which have equipped them for admission to university on the basis of ma points. The University has developed innovative alterna selection programmes to identify students with potential.

Non-matriculated candidates may be selected to stud the University through selection by one of the following altei tive access programmes.

APPENDIX 14

BOITJHORISONG INTERVIEW:

(On Task 2)

It was after that the questionnaire tasks were distributed and were responded to by the Boitjhorising teachers and the data collected that the interview session was started. There was not much time left and only the interview about Task 2 could be processed:

I :On the ball at position 1, how many forces and what are their directions?

[After some silence]

B1 :There are three forces: the one applied from the throw, there's also external unbalanced force, and the last is the force pushing the ball upwards.

I :Who is differing with you or who wants to add? Remember, it is going straight up - how many forces?

B3 :I think there are only two forces: it is the force that pushes the ball up and the force of gravity that presses the ball down [B4 was impatient wishing to interrupt].

I :Yes, you can interrupt if you like [pointing at B4].

B4 :But if you talk about forces, then I think there is only one force on the ball, the only thing that changes is the energy of the object ...

I :Let us speak about forces!

B4 :I should think that there is only one force, gravitational ...

B3 :[interrupting]...If there is only one force, then if you throw it upwards it will just return down where it started, that is, as it is thrown upwards, it would just change direction and fall down; but at position 1, since it was moving straight upwards, it shows that there is upward force ...

B4 :[interrupting]...The only other force will be air resistance ...

I :Let us stop this argument at that, we will have it resolved.

APPENDIX 15

UNIQWA INTERVIEW

(On Task 2)

Uniqwa is the Qwa Qwa Campus of the University of the North situated in Maluti Highlands in the North Eastern Free State. When the investigator was still working, he was lecturing physics in this institution. For one hour he was allowed to collect the data among students here. The interview could only be carried out in the ten minutes which were left after written results were collected from the students who were the study subjects. There were 14 students participating in the study at Uniqwa. It is worthwhile to mention that only five of them were active in open discussions in the interviews. The rest were quiet and passive. For the sake of confidentiality, the names of the subjects are withheld and they are only labelled U1, U2, U3, etc at Uniqwa, while the investigator is I. The interview time given was only for Task 2.

(The subjects had already seen and responded to Task 2 which was about a ball thrown up and was indicated at three positions):

I :Let us talk about forces at position 1. How many forces?

U1 :There are three.

I :Somebody says there are three. What do other people say?

U2 :One.

[Suddenly a quarrel started. Even those who were quiet responded openly and loudly at U2. This shouting participation was condoned , and even those who were quiet were showing life now. A strong contingent of these subjects emphasised two forces].

I :Other people say two, one says one while others say three forces. You say one [pointing at U2], which force is it?

U2 :I say one for gravitational force downwards.

I :When you say two, which forces are they [pointing at U3]?

U3 :It is the force input by the hand ...

I :It has already left the hand!

U3 :The force of gravity and the upward force.

I :OK! you said three forces [pointing at U1].

U1 : Other third force will be what is an additional force

I :Thank you, ladies and gentlemen for having me and for having answered the questions so generously.

APPENDIX 16

TSHIYA INTERVIEWED

Tshiya College of Education is situated in Qwa Qwa. Among many data collection sessions the investigator carried out about teachers pre-service and in-service, Tshiya was having a number of them. The following is one of several chatting interviews which were carried out:

I :What do you think about this questionnaires?

F1 :We call everything matla ...

F2 :[interrupting]...It is uncomfortable to call everything matla, matla for power, matla for strength, matla for force and matla for energy.

I :What about Air Force, Police Force and Defence Force?

F3 :They are confusing.

I :At varsity a gentleman Bomber grabbed a lady for a love affair. He seriously approached her :

"Lady, I love you!" he said.

"No Sir, we are not here for ..." before she completed her response, the gentleman answered, frowning: "Lady, I am not asking what we are here for, I tell you, I love you!"

" Sir, please do not use the Vector Quantity" answered the lady who had learned in physics that force is a Vector Quantity.

[The class was very interested and very attentive as well to the story, it is an accepted norm among them to grab and be grabbed in a similar fashion].

I :Was she right or wrong about the Vector Quantity?

F1 :She was right. The gentleman used force with direction towards himself to be loved.

[There was a great quarrel among the subjects where some agreed with F1 that the gentleman had applied the Vector Quantity, some refused since there was no contact].

I :Does this kind of force have any measurable magnitude?

F1 :Yes, the more furious the gentleman, the larger the magnitude.

I :Let us end it at this point because we will otherwise go beyond the time stipulated for our interview.

APPENDIX 17

Teacher Ma interviewed

Teacher Ma has been teaching physical science at Mampoi Secondary School for over fourteen years. She has a Bachelor of Science degree with first year physics and mathematics. She is known to be a very courageous teacher who, besides attending to her students even after hours, she was always very keenly donating her time to general students in Qwa Qwa during Winter schools over many years. Once she received the message that an interview was needed with matric teachers in Qwa Qwa, she indicated that she was very keen. She is a open person who, if she knows one well, she speaks freely and at length to stress her point. She was then approached for this interview:

I :Good morning teacher Ma. You have been teaching physical science in this school for more than ten years. Can I ask you question after we have read this story? They are not difficult questions, they are matric questions.

Ma :E-ya, Ntate Moji, you are right (Yes, Mr Moji, you are right).

The story of Moshoeshoe's wars was read

I :Now question one: as boulders rolled down which quantity or quantities did they gain?

Ma :They gained acceleration.

I :Ok, they gained acceleration - anything else?

Ma :I can say they also gained momentum.

I :Momentum, yes - what else?

Ma :I think that's all that I can give.

I :Can you express them in your language? What can you call momentum and acceleration in your language, ka puo ya heno (in your language)?

Ma :Ka puo ya ka? [she was very surprised, she did not expect to be asked to say it in Sesotho] Akere di "gain-ile" acceleration, lebelo leo di tsamayang ka lona le eketsehile (in my language, isn't they gain acceleration, lebelo with which they move has increased).

I :Ok, momentum ona ke eng?

Ma :Momentum nkare "mass and velocity" di tla "change-a" (momentum I can say mass and velocity will change).

I :Ke batla ho hlalosetse motho eo e leng ngwana wa matric o se ke wa hlalosetsa nna (I would like you to explain to somebody who is a matric child, do not explain to me).

Ma :Ka Sesotho Ntate Moji (In Sesotho Mr Moji)? Nkare (I can say)...[quietness].

I :We are going to the second one: when a boulder is rolling down, it collides with a stationary one. What does it impart to the stationary boulder?

Ma :Obviously it gives kinetic energy.

I :Ok, you say kinetic energy, anything else?

Ma :And one other thing, it also gives momentum to the next boulder.

I :Ok, etjho ka Sesotho he (Ok, say it in Sesotho then)!

Ma :Ke hore Kinetic energy ke bokgoni ba ntho e tsamayang hore e ka sebetsa (it is that kinetic energy is "bokgoni" of a moving object to carry out some work).

I :Na kinetic energy ha e na lentswe la Sesotho (does kinetic energy not have a Sesotho word)?

Ma :Tjhe, ha le yo, Ntate Moji (No it is not there, Mr Moji).

I :Ok, jwale momentum (now momentum)?

Ma :Ha ena lentswe la Sesotho le yona (it also does not have Sesotho word). Ntho e neng e tsamaya, e na le momentum, e "cause-a" e nngwe hore e tsamaye, e "lose-a" lebelo la yona e leng "velocity" e le file e nngwe (an object which was moving having momentum, causing the next one to move, loses its velocity to the next one)

I :Ke batla dintho tseo ka Sesotho, bo-velocity , bo-momentum (that is what I need, velocity, momentum)!

Ma :Nkeke be ka re ke lebelo hobane ka Sesotho ha ke re lebelo nka nna ka re ke velocity, kapa acceleration kapa speed. Jwale ha ke na "precise word" ya velocity ka Sesotho (I cannot it is lebelo in Sesotho, is it not that lebelo can be velocity or acceleration or speed? Now I do not have a "precise word" for velocity.

I :Let us go to the third question: Some falling boulders can kill a man, for such a boulder to kill a man it must have a large amount of (a quantity).

Ma :It can be mass, it can be its velocity, it can be kinetic energy.

I :What are these quantities mass, velocity and kinetic energy in your language?

Ma :Mass is boima, hape velocity ha e hlaloswe ka Sesotho Ntate Moji, kinetic energy le yona e thata (again velocity does not have Sesotho word, Mr Moji kinetic energy still, is difficult).

I :Let us go to the fourth question: Some small boys could not even move some boulders. Now in terms of some mechanics concepts, what is the difference between boys and men?

Ma :The difference is their mass; for these to roll the boulders up, they need a certain amount of weight.

I :Let us come back to it, I think I like that one. You say their mass, the mass of men and boys or the mass of the boulders?

Ma :The mass of the men, the boys and the boulders to the boulders [stressing with hands indicating a push].

I :Ok, why do you think a boy needs to have some mass?

Ma :For this boulders, say it is 100kg, a minimum force to push it must be 1000N; so boys with small mass, maybe 11kg will only apply a weight of 110N which will be very difficult for them to meet the requirement; at least if they are three, they will meet the requirement.

I :So then in order for the men to be able to roll the boulders of 100N, they must at least...

Ma :[Interrupting]... be able to exert that 100N, but to roll it upwards, it must be more.

I :Alright, let me ask you the last question: Man X and man Y. They are rolling two identical boulders up the mountain, along the same length of route. Man X arrives ten minutes before man Y at the top. What do you think is the difference between man X and man Y, mechanically?

Ma :The other man delayed.

I :Yes, and then why?

Ma :He might have exerted lesser amount of energy, moving slower.

I :So if somebody ...

Ma :[interrupting] the motion of the stone depends on its mass and its velocity, so if they are having the same mass and the other is causing less velocity to the stone, is going to be delayed.

I :Ok, has power got anything to do with this?

Ma : Akere (is it not) power is the amount of work done in a certain period meaning that the one who was moving slower, meaning that he is having less power than the one who was moving fast.

I :So you say the one is having less power than the other?

Ma :Yes, than the other one.

I :Thank you very much. Do you have three minutes that we can go into the second task [she was preparing to go to the next class]?

Ma :Yes! [she received the sheet where Task 2 of the ball thrown up, was laid out].

I :In this second task a ball is thrown up, going until it turns at the top and it comes down. Now we are looking at the ball after that it had left the hand. How many forces at position 1 are acting on the stone? Let us neglect the air resistance.

Ma :The force might be gravitational attraction between the ball and the hand, the weight of the ball downwards and the force that had been exerted by the hand upwards.

I :Ok, are there forces on the 2nd position?

Ma :Weight of the ball downwards because it is now stationary. The force that the ball experienced after it has been pushed by the hand has been overcome by the air resistance, now only the weight of the ball downwards.

I :Let us come to position 3. How many forces are on the ball at position 3?

Ma :I think is still the weight of the ball downwards, the mg.

I :Ok, let us go back to position 1, what has happened to the force that has been facing upwards?

Ma :The force that has been used to throw the ball upwards has been balanced. It was greater than the ball's weight at position 1. At position 2 where the ball is stationary, the forces are now balanced, but immediately it starts going down, the gravitational force exceeds the other force.

I :What would you say to somebody that would say there's never an upward force when the ball has left the hand?

Ma :How come the ball has gone and continues upwards without the force upwards?

[The time was very limited by then, she had to go but she was an interesting participant]

I :Think about it, I will talk to you some other time.

APPENDIX 18

Teacher Mm interviewed

Teacher Mm was teaching physical science in Mmapoi Senior Secondary School during the time of this interview. He has taught in some high schools in the Qwa Qwa region including Selelekela Senior. He has graduated from Uniqwa with first year physics passed in his B. Sc. degree. The investigator knows him from the time when they volunteered to run Winter school for Qwa Qwa matriculants in the early eighties. He was happy to offer himself to be involved in the interview with the investigator. It was a relaxed interview conducted "chattily".

I :You are going to forgive me because I am going to cassette all the information because I am going to write it down; but I want you to be free to talk to me because Wena (You) teacher Mm have been teaching physical science for some ten years for matric. Now I am having a little story here, we are going to read it and there are five questions you are going to answer. They are simple questions, in fact, they are matric questions:

Moshoeshoe's wars story was read

I :I am going to ask you the questions. You are going to give the answers in English and in your language; you are not going to use the terms strong, strength, stamina, might and mighty because we don't use them normally in physics. So there are five questions you are going to answer. Now the first question is: as the boulders roll down the mountain what quantity or quantities do they gain?

Mm :They gain momentum

I :They gain momentum, and anything else?

Mm :Of course, energy.

I :Which kind of energy? You know physics says even heat is energy.

Mm :Kinetic energy.

I :Anything else?

Mm :They gain force.

I :You say they gain force - anything else?

Mm :I think that is all.

I :Alright, momentum ke eng ka Sesotho, ka puo ya hao (what is momentum in Sesotho, in your language)? I want it in your language.

Mm :Momentum nkare ke lebelo (I can say momentum is lebelo).

I :Ok, kinetic energy?

[long pause]

I :Akere jwale re hlalosetsa ngwana hore kinetic energy ke eng (when we wish to explain to child what kinetic energy is).

Mm :Ke matla (it is matla).

I :Ok, the other quantity is force. Force re re ke eng ka Sesotho? (what do we say force is in Sesotho?) [long pause]

Mm :Ke ho sututsa kapa ho hula (it is to push or to pull).

I :Now we are going to the second question, easy questions, when the boulders collide, what does a moving boulder impart to the stationary boulder?

Mm :In collision, obviously, there is a conversion of energy.

I :It gives energy, what kind of energy? and anything else besides?

Mm :Momentum and acceleration.

I :Anything else? You said energy, momentum,... [interruption]

Mm : and some force.

I :So three of them ka Sesotho ke ding? ntse di tshwana le moo...(what are they in Sesotho, are they still the same...) [interruption]

Mm :E, di ntse di tshwana (Yes , they are still the same).

I :Let us go to the third question, you see there are still two more questions. Such falling boulders can kill a man, for such a boulder to kill a man, it most have a large amount of some mechanics quantity, what mechanics quantity should it be?

Mm :a large amount of energy and force, impulse - that's enough

I :Ha re di bue ka Sesotho (Let us say them in Sesotho).

Mm :Impulse ke sekgahla (impulse is sekgahla).

I :Force e ntse e tshwana (Is force still the same)?

Mm : Force e ntse e tshwana le energy (force is still the same with energy).

I :Ok, let's take the last question: some boys could not even move the boulders; in terms of mechanics concepts, in what way are the boys different from the men?

Mm :I think is force.

I :What did force do, or what happened to force?

Mm :The difference is the force that they apply, because force depends on mass and acceleration. If you have larger mass, obviously the force that you apply will be higher.

I :You say obviously your force will be higher?

Mm :E, (stressing) force depends on mass and acceleration.

I :So you still mean it depends on the force that you have? - Ok! The last question then: Man X and man Y are rolling identical boulders on the identical path up the mountain, but man X arrives at the top of the mountain ten minutes before man Y, in mechanics concepts, what is the difference between the two men?

Mm :I think, Ntate Moji ke force (Mr Moji it is force), the pushing force, tension which depends on acceleration but g is the same for both.

I :So you mean that they push with the different forces?

Mm :Yes

I :Does power have anything to do with their action?....[silence]. Anyway, thank you.

[There were few minutes we could still use to talk further, so Task 2 was quickly grabbed and handled. Looking at the figure and speaking together about it].

I :If we are neglecting the air resistance, how many forces are on the ball at position 1?

Mm :They are about four.

I :Which ones?

Mm :Tension, weight, horizontal force and the pushing force.

I :At position 2?

Mm :At position 2 you've got tension and weight

I :At position 3?

Mm :You've got tension and weight.

I :What is the direction of tension?

[There was a long silence].The investigator thanked him, he had to go, his class was starting.

APPENDIX 19

Teacher Nts interviewed

Teacher Nts was is a B.Sc. graduate of Uniqwa whose degree has Botany and Chemistry as majors. She did study the first year physics where she was a student of the investigator. She had always thought that the investigator as a lecturer in physics was a very difficult person who did not want students to pass. She had been teaching physical science for three years by the time she was requested for an interview. Although she agreed to be interviewed, she was very reluctant; most of the responses were begged from her, while she also was not willing to speak English. The interview went on as follows:

I :Good Day, Nts, how are you? It is good to see you. What do teach at your school?

Nts :Ke ruta (I teach) physical science.

I :Do you like it, I am sure you are doing well. I wished to see you and ask you some questions for a research study.

Nts :Ae, Ntate Moji o bapala ka nna (No Mr Moji you are not serious with me).

I :When a rock is falling on a man, killing him, what must it have, what is the quantity it must have in order that it must kill him?

Nts :Ke weight (Is weight).

I :Weight, Ok, anything else?

Nts :[silence] ... le mass (and mass).

I :Ok, what is weight in your language?

Nts :Ke boima (It is boima).

I :And what is mass?

Nts :Le mass ke boima (and mass is boima).

I :We go to another question: when small boys are trying to roll the boulders, they cannot move, but men roll them. What is the difference now? How are men different from boys?

Nts : Ba na le matla a fapaneng, ekare bale ba sa le bannyane (they have different matla, the others are still young).

I :Ok, say it in English, my dear, please!

Nts :Ae, ha ke tsebe Sekgowa Ntate Moji (No, I don't know Sekgowa, a Whiteman's language).

I :No, no, but is it not that you should be teaching in English!

Nts :I am teaching in Sesotho [laughter].

I :No, your children will fail. Ok, what is it? Ba na le matla, I am happy about that. Now say it in English, please. What is the difference between boys and men? in English now!

Nts :The difference?

I :Yes, I mean you said ba bang ba na le matla, now let us say it in English.

Nts :Ka mantswe a mang force eo ba e apply-ang e a fapana; banna ba sebedisa e ngatanyana than the boys because the boys ba sa le tlasenyana (In other words, force applied is different, men use more force than the boys, since the boys are still young).

I :Ok, the last question. Man X and man Y are rolling the rocks up the mountain. This is the last question. They are rolling the identical rocks on identical pathway but X arrives ten minutes before Y. What is the difference?

Nts :Akere yane o faster than the other one, o arrive-a pele because enwa o sebedisa speed se matla ho feta sa yane (that one is faster than this one since he uses speed with more matla than the other).

I :Thank you Nts, you are still difficult even now, i hope you are not this difficult to you school children and the principal.

APPENDIX 20

THE INVESTIGATOR'S STUDY LIFE STORY

I was born and bred in Witsieshoek in the Free State. I went to Tshiya High School from 1967 where I learned physical science which consisted of physics and chemistry. I was warned that it was only a few years since it was introduced among the blacks because it was really difficult for them. I studied and succeeded because it was not much of a problem to swallow the formulae, definitions and derivations. Concepts in mechanics were different from those with the same name in everyday life. Force in the classroom was not the same Air Force, Police Force and Defence Force; neither even electromotive force nor the force we use to force girls to love with; force in physics rather has to do with masses and accelerations, the terms and conceptions not usually used in some of our daily language, worse still if English is one's second language.

I nevertheless succeeded with my rote learning and regurgitation in physics, through my technological training where we had to have at least physics passed in the first year. I succeeded through a junior degree in physics as a major, but still remembering the statements of the physics lecturers and the mathematics professor. The science that was not for the "Bantus" was haunting me. Somebody, needed to verify this statement from these learned gentlemen.

We, the indigenous people, had been classified in South Africa in those days as Bantu people who were barred and limited in several ways politically, educationally and otherwise. We were the fourth class of people in the order of inferiority, and hence the most dejected following the Coloureds, whom I have learned are, inter alia, the cross breed from white Colonialists and enslaved African women (Moji and Moji 1993), who in turn, followed in the order of oppression, after Indians, whom I have learned were imported from the East to process sugar in Natal sugar plantations. Indians, though were in the list of the oppressed, were the least oppressed (Moji and Moji, 1993). As indigenous and native to the Southern tip of the African continent, I thought it would be appropriately accepted for the native people alone to be called Africans, but lately it has occurred that the other population groups, also called themselves Africans since they were born in Africa, as Ms Patricia De Lill, a well-known figure in the Pan Africanist

Congress of South Africa, argued in a Felicia Mabuza-Suttle show.

I have thus been born a native boy in the days of separation called apartheid, growing partly in a Native Reserve in remote Witsieshoek and partly in an "advanced location" or township of Sharpeville. We have been called names: Natives, Bantus, Plurals, Kaffirs, Blacks, Africans and others depending on who was calling us and what it was that we had done or were to do. In most cases we carried these names given to us wishing to succeed with the minimum of troubles from the oppressors. We would agree to be called any of these names in order that the day would at least finish without being thrashed. There were those of us who were fortunate to afford to go to school beyond matric either from farms or Native reserves later named Bantu Homelands.

Many different words of advice and warnings were given to us in those days, such as the advice of a Turfloop professor telling us that Mathematics was not for Bantu and women students, worse with Bantu women; he was literally not recognising the ladies in the lectures but was addressing us as only "Gentlemen". The Bantu gentlemen had to know that they were only limited to a junior degree in science (B Sc); if they would be fortunate enough to complete it, they must change the career direction to faculties like Arts and Education, because Sciences such as Mathematics, Physics and Chemistry were not for the Bantus.

It bothered me from that time and I wanted to find out why the sciences such as Physics were not for the "Bantus", etc. Were they not understanding physics as it was taught to them by those so called professors, or are they really not that clever to understand, in fact, too stupid to conceptualise the "sophisticated" physics? The physics lecturers in those days of 1972 were telling us off in the practical sessions when we were dealing with error analysis, we were told how foolish we were, how we did not deserve to be in physics, how we would never make it, how it was never meant for us to be in physics. They were white, we were all black, or at least native or indigenous. What was it that we lacked or were weak in, in which they were so much better and educationally strong, in comparison with other population groups, particularly that even in population classification so derogatively undermined; being given universities that are so understaffed, underequipped laboratories and undersupplied libraries; being shut out in Native reserves and Bantu Homelands far away from civilization where our cries would not be easily heard.

I would not be content before I find out what was it that made professors to think we cannot understand physics as Native people. I do not know what the case is in understanding physics by the other population groups ahead of us in the ladder of classification, that is, the Coloureds, the Indians and the Whites. Since, there are however, very few of us Africans beyond the Masters level of physics studies in South Africa where there are over twenty universities to study from, there must indeed be some problems studying, understanding and succeeding in physics by the so called Africans; what is it? With some great difficulties I came through that physics bottle neck, at the time when there were not more than thirty Africans at that level in South Africa, thank God. I now consider it my duty to this Country to find out what this bottle neck is all about; what *is it* that prevents the African people from understanding physics?

I have been fortunate to be a physics lecturer for some time (ten years) in one of the historically Black universities. In a way I think I have noticed a tip of the iceberg of the problems and difficulties the African students have in understanding physics the way physicists expect it to be understood, particularly because culturally we as Africans understand concepts differently from, say, the western people. Seretlo (1973) and Cobern (1996) noted this fact, among others. I have noticed multitude of African students struggling with the same concepts I have struggled with and those I still struggle with presently; I have therefore taken it upon myself to pry into some investigation of these problems; they are very wide, they can never be adequately handled in one investigation and be done. I find it to be my duty to conduct some of these investigations, some other investigators will follow up and do further investigations which I could not manage. However, I trust that they will all alleviate the difficulties of the African children to understand physics the way the physicists wish it to be understood.

APPENDIX 21

Responses and Translations from African subjects of the Student group on Question 4

It is necessary that the responses and the translations of the African students within the Student group be recorded as they were given. It is the responses to Question 4 of the Task 1 modified for the Student group. They were very interesting responses from which many aspects were discovered which were otherwise not expected. The question was: Some small boys could not even move the boulders; in terms of mechanics concepts, in what ways are the boys different from men? They are grouped according to their languages:

Tsonga responses and translations (they were 3)

they have small power	No translation
boys have less energy	abanawo amandla (translated into Zulu)
they haven't got enough force(cancelled power)	No translation

Setswana responses and translations (they were 4)

men have more mass	No translation
men can exert enough force	ba na le matla
force	thata
they provide less momentum	No translation

Sepedi responses and translations (they were 4)

no work done by boys	Ga go mosomo
energy	No translation
no experience	ga go botlhale
less force exerted	matla a mannyane

Sesotho responses and translations (they were 5)

force	hula - sututsa
energy not enough	No translation
less mass	Ba fokola

have less power	Ha ba na matla
no response	

Xhosa responses and translations (they were 7)

relative to their mass	abanawo amandla
long arms with less force	No translation
less force applied	amandla amancinci
less force less energy	No translation
have less weight than men	ubunzima obuncinci
force	No translation
no response	

Zulu responses and translations

men have more power than boys	No translation
boys could not apply enough force	No translation
F (b) < F (m)	No translation
boys do not have much force	abafana abanawo amandla
weak or powerless	abanamandla
they have small masses	banezisindo ezincane
their applied force is less	amandla abanawo mancane
boys have less energy	abafana banamandla amancane
boys have small radius	abafana banomqolo omfishane
force	amandla
less energy in boys	abafana banomfutho omncane
boys have less strength	abafana banamandla amancane
force they applied cannot overcome	abanamandla
weight too small	abanawo amandla
they don't have enough power	abanawo amandla anele
not have enough energy	abanawo amandla anele
bones not fully developed	amathambo akakaqini
don't have enough energy	abanawo umfutho

less power	amandla amancane
less power required to move	amandla mancane awuwaqubula
men have more power	amadoda anamandla
they do not have enough power	abanawo amandla alingene
their masses are not he same	abalingani ngesisindo
the force applied by the boys	amandla abafana mancane
they don't have enough force	abanawo amandla awenele

boys have less power than men	abafana banamandla amancane
they are young to have enough power	bancane abakabinayo amandla
men have more power	amadoda anamandla
boys do not possess force	abafana abanawo amandla
energy that boys had	amandla abafana
they do not have much energy	amandla abafana mancane

There were two Zulu subjects whose home language was said to be English. They did not give the translations but both responded that the difference was the force applied.

The responses from the Indian subjects were interesting too with no translation of course

boys not have enough power	exerting force
size	boys have lower mass
exert smaller force	amount of force
have less potential energy	force used
exert larger force	cannot exert enough force
angle	weight
force applied	

less mass less force	men have more power
force applied	less mass, less force applied
did not have power	men have great force
have small mass, exert small force	power possessed
force exerted	power

inertia mass small, E-potential small	force exerted
did not exert force	force exerted

and 6 subjects did not give responses

APPENDIX 22

Teacher Bofelo interviewed

Moqhaka is a Senior Secondary School in Sebokeng - Vaal Complex in Gauteng. Although this school is outside the realm of the present study, a short interview was carried out with teacher Bofelo at this place and the outcome of the interview was interesting to the investigator. He had already given responses on the questionnaires of Task 1 and Task 2. The short interview was thus following the responses to the questionnaires:

I :How was the questioning?

Bofelo :The questions reveal our problem area.

I :Which area is that?

Bofelo :We are stuck on English because we do not have enough vocabulary in our vernaculars.

I :Do you think we can teach physics in vernaculars?

Bofelo :Not at all; maybe a mixed language. There is a lack of understanding because of language.

I :When I was at the Varsity in Turfloop, Bomber was a third year B.A. student and Kitty was a B. Sc. fresh lady. Bomber came to Kitty frowning and said: "Lady, I love you." Kitty answered: "Sir, we are not here for ..."before she finished Bomber interrupted: "I am not asking you, I am telling you!". "Please, Sir, don't use a vector quantity" said Kitty almost sobbingly . Was Bomber really using a vector quantity?

Bofelo :Oh yes. Bomber was applying force on Kitty.

I :What was the direction of the force applied?

Bofelo :Towards himself. The force was pushing Kitty towards Bomber.

I :But they were not in contact.

Bofelo :No. This was a theoretical force and not a physical one; the magnitude was how horrible Bomber's frowning was; the more horrible, the larger the magnitude. It was the same case in the questions about Moshoeshoe's enemies climbing up the mountain with a theoretical force in the direction of Moshoeshoe. The angrier the enemy, the larger the magnitude of the theoretical force they have.

I :Thank you, Mr Bofelo.

APPENDIX 23

TEACHER KHALIPHA INTERVIEWED

Fezeka is a Senior Secondary School in Gugulethu, in the Cape Peninsula. Although Fezeka is a school outside this study area, there are some interesting facts in the interview. Khalipha is a teacher responsible for teaching Physical Science in this institution. She was given Task 1 to answer and was interviewed thereafter. She sat down after handing in her written answers, eagerly awaiting the interview. There was not much time to carry out a long interview, nevertheless, a short interview was managed. The transcript of the interview was as follows (I standing for the investigator and Khali for Khalipha).

I :What do you think about all these questions?

Khali :The questions show that our vocabulary is very poor.

I :Does this vocabulary poverty affect Physics learning?

Khali :Yes. When you teach not knowing that your students have only one word for all these science topics, you will teach not giving attention to this vocabulary poverty of your students, and will not overcome the poverty, while your students will not learn properly.

I :What do you do to address this problem of vocabulary poverty?

Khali :For a number of years while I taught Physics I discovered the difficulties among students every year that they did not notice the difference among the Physics terms that are close to one another. Now when I start a new topic, I highlight the terms which the students usually have problems with in that section. I write them on the board and explain all that the term means and is used for. If a chapter contains the word "conductor", I write it, ask the students what they think it means, and explain how we are going to use it. This conductor may mean a choir leader, a person in a bus or train telling us where we are, and I continue until I arrive at how the conductor can be a current conductor.

I :Does this strategy help you?

Khali :It resulted in a great difference.

I :Thank you very much for this strategy of yours Khali. I will apply it where I am working.

APPENDIX 24

Steve and Mike interviewed

I :Ok, gentlemen, we are going to look into some Zulu words for the concepts that we are using in physics. You have seen these concepts and you have filled the papers that were asking you about them, but today I just wanted to check further. There will be three groups that we'll speak about. The first one will be the group of speed, velocity and acceleration; the second one will be the force, energy, momentum, impulse and power and the third one will be the small one, namely, heat and temperature. We would just want to look into how different these terms are physics-wise and Zulu-wise. So manje-na ke, may we please start with: What is the meaning of amandla? How do you feel Steve? Say that in English, what is amandla in English?

Steve :Must I explain that or must I just translate?

I :Ok, if you can do both, do both, just explain and translate.

Steve :What I understand about amandla? If you have more amandla it means you have more power.

I :So amandla is something that a person will have?

Steve : Yes.

I :So for amandla you will say power - how do you feel, Mike?

Mike :Yes that's what ca me to my mind as well that amandla means power and energy.

I :Ok, lets go to the second one: What is umdlandla?

Steve :If you have umdlandla is when you are lively, when you are active, you walk like jumping in liveliness, and when you are lively you can have more power although you are not necessarily powerful.

I :Ok, how do you feel, Mike? umdlandla?

Mike :To me, I thought umdlandla could be courage, you are courageous, unomdlandla or else energetic, somebody energetic is ....[Steve interrupting].

Steve :What do you mean by energetic?

Mike :In Zulu, to me it will mean ubasenamdlandla.

Steve :Yes, just explain in English, what do you mean by energetic? Do you mean he has got more energy?

Mike :Yes, for sure in English it has to mean you are having more energy to do something.

I :So that would mean that umdlandla, we want to associate it with energy? we could say that it is meaning energy?

Mike :Yes.

Steve :But I would disagree.

I :What would you call energy in Zulu now? You are saying you are disagreeing with Mike when Mike says umdlandla and energy would go together or they mean the same thing. What is energy in Zulu theway you understand?

Steve :Yes, I think when you are hungry I could say you need some energy. I could say you don't have umdlandla. I could say there is connection between energy and umdlandla in that sense.

Mike :Now you agree that umdlandla .....

Steve :Not directly.

I :Ok, gentlemen, let me ask you the third word: Umfutho. I tried to look at umfutho in the dictionary, both dictionaries do not come out with umfutho. So what is umfutho? Ok, we can start with you, Mike.

Mike :Umfutho [quiet for a long time].

Steve :Umfutho! The one way of explaining that could be: If I'm throwing a tennis ball towards a wall, if I'm throwing ti faster, it has more umfutho; and when coming slowly....., but it doesn't mean umfutho is big....., but let's say there's a heavy body which is not travelling so fast, I wouldn't say it has more umfutho because even if it's heavier, if it's travelling slowly I wouldn't think it's a good thing to say it has umfutho.

Mike :Umfutho, I think it means to add more force. Umfutho.

Steve :Force! You mean force in the form of pulling and pushing?

Mike :Imagine you can say "Faka umfutho" uyabona (you see).

Steve :Yea, even in boxing! You can say his punches haven't enough umfutho. You can say that Izibhakela zakhe azinayo umfutho, force, our knowledge of Zulu is limited.

I :What would you say about umfutho and momentum? Would umfutho be more momentum or more force? [quietness].

Steve :If momentum is great, either mass or velocity is great, or in a loose language I could say that, not necessarily true but either velocity must be great or mass .....

I : Tell me, Steve, would you say that...[the phone rang, we stopped]....

Steve :For momentum, either velocity or mass must be large but now with umfutho I think either the object is small or large, it has to travel fast for umfutho to be large.

I :So it will not so much tally with the explanation of momentum?

Both :Yes!

I :Do you think from the three words, amandla, umdlandla and umfutho, do you think there are explicit and precise explanation of what they mean? Or do we, as we speak Zulu, randomly have these terms applied? Would you think amandla is precisely defined, and umdlandla can be precisely defined and umfutho can be precisely defined?

Steve :I just come in very quickly there, I can say maybe we don't know, it would be fine to ask language specialist maybe.

I :There I must just end up by saying that it's so difficult because a Zulu language specialist tends in most cases not to be a specialist in Physics such that the definitions in Physics would differ from the definitions in Zulu because when I look in Zulu-English Dictionaries it turns out that force and power and energy are all given out as amandla, so I still fear that somebody that was putting together the dictionary is not a person in Physics; now the reason why we are together as physicist, we would like to look at "maybe the students will understand when I mean this particularly in Physics"...let us pass by .....

Steve : ..... and then trying to use words that she or he already knows in trying to explain ...

I :Yes.

Mike :Did you get the Zulu equivalent for momentum?

I :Let us come to that Mike, we are done with the first part where we were speaking about the three words. So we come to the second one. We have got these four or five words. I want us to give the Zulu words for power, energy, force, momentum and impulse. You remember that in Physics they are explicitly different terms, they are meaning different quantities. So what would we say is the Zulu word for power?

Steve :There is no doubt, amandla.

I :So power you say no doubt amandla, I don't know if Mike will not doubt that, Ok Mike,what do you say?

Steve :We don't have to invent new words, we just have to use the words we already know.

Mike :I would say, yes, but I am not saying without any doubt.

I :Ok, we go to energy. What is energy in Zulu? Steve?

Steve :A more closer word for describing that I would say umdlandla.

I :You say a more closer, but you still have some doubt, in the first one you said no doubt. Ok, Mike?

Mike :I would use amandla again.

I :Alright, we go to force; force, Steve?

Steve : I've never heard any word. I've never heard or thought any single word that can describe force.

I :Ok, Mike, how do you think when "Z" says there's no Zulu word for force that he can think of, how do you feel, Mike?

Mike :Mina (Me) I would use umfutho for force, from the common saying if you've got to add more force we use to say "faka umfutho".

I :You would use umfutho for force?

Mike :.....amandla, so to me in actually means in English.... You've got to add more force.

I :So you are settling for umfutho or amandla?

Mike :I am opting for umfutho!

I :For force?

Mike :Yes.

I :Ok, we are coming to momentum. [Mike was whispering that it was confusing] I know it's confusing. Steve, what would you say it's a Zulu word for momentum?

Steve :Ah, well, again I would say there is no single word, but in describing what momentum is, I'd definitely include the word umfutho. In favt I can also include the word umfutho in describing force, not that that word would solely describe the words.

I :Mike, momentum?

Mike :I think umdlandla is the best as far as I'm concerned.

I :Can you be able to say anything about impulse?

Mike :I think impulse is lost in a Zulu way of .....

Steve :Of cause impulse is force per unit time......?

I :Although I would not love us to interpret these things in terms of the formulae they are expressed in, yes, it is Ft, force times time

Mike :I don't think we have a word in Zulu .....

Steve :So that the greater time you spend applying the force.....

I :Yes is the impulse, the time you are taking in applying that. Alright. Don't worry I also feel we don't have it in Sesotho in any case. Alright, thank you very much we have done with this part. Two last parts are left. Let us go to the third one: What is the speed in Zulu, Steve?

Steve :Jubane, another synonym is isivinini.

I :Do you agree, Mike?

Mike :I say jubane, not isivinini, ijubane.

I :Ok, I have a suspicion that Mike is already putting isivinini for something else [laughter]. I have a suspicion that Mike is not fair becuse he is already suspecting that there is another word coming, he is going to apply this where the first one is jubane and the second one is isivinini. Ok, what is acceleration?

Steve :According to my own knowledge there's no single word in Zulu that describes acceleration.

I :Alright, how do you feel, Mike?

Mike :Yea, I feel the same as well.

I :Alright, let's come to velocity.

Steve :There's no differentiation between speed and velocity, it is just ijubane.

I :You feel different Mike?

Mike :I would use isivinini for velocity [laughter].

I :This is what I suspected, while we are finishing up that group, some other school students come up with things like isipidi. Have you ever heard such a word?

Steve :It is umfakela, just like if we say itafula.

I :Because I thought those were the word that was coined from speed. He decided that because speed has got a certain definition so he just said isipidi and maybe the day when we are coining up the words for Physics so that Physics would be audible we would say isipidi, iacceleration noma (and) whatever; let us come to the last issue: to the teachers at school, do teachers, do teachers happily teach Physics to students maybe in matric or teacher training colleges or do they pick up some problems? Particularly when some students come up with the ideas like isipidi? I had suspicion that maybe it is because some teachers have been trying to coin out the terms so that they could tally together with meanings of Physics.

Both :We have no personal experience for that.

I :Do teachers at school not struggle with all these terms?

Steve :There is no exact event we can remember concerning that.

I :One other point which I also want to mention in here is one the answers that many people mentioned, you remember that question that some boys could not even move some boulders, the reason that I was getting was because the boulders had more mass than the mass of the boys. How do we feel about that issue? Do we feel that we can only move something which has got the same or less mass than you have? How do you feel Mike about that?

Mike :No, not the case.

I :Let me ask the last question. The last question is, it is interesting. Are all the instructions clear that the force that we have to apply has got to be the interaction between the two, that if I'm pushing the boulder the boulder is also pushing back to me, not necessarily that the force is something intrinsic in me and that I can walk along with my force and walk away because the force is mine, is actually embedded in me and I can go away with it or I can take it out and push the boulder and just give it to the boulder and the boulder would move from it; would that be clear because I have never understood that, it is only recently that I have understood that force actually is not...if I am pushing, it's not that force is something within me but it's something which is existing, but an interaction existing between us because even if I push you, even though you walk away you are also pushing back to me. Is that, Mike clear at matric level amongst our students or is that what we naturally pick up at university level?

Mike :No, not at school level, myself, I don't have any experience in Physics teaching at school because I never did Physics at school, I did General Science at Standard Seven and no Physics in my curriculum. I don't think they do any explicit distiguishing in terms of explaining that force that force is not something you carry around; the way they use these terms is just to actually try just to teach about them.

APPENDIX 25

Mr Q interviewed

1. Mr Q is a Sesotho speaking physicist. He was a head of Physics Department of the National University of Lesotho when the investigator visited him. He was included in the investigation because there are few physicists within the Sotho group of the population. For a long time it had been difficult to make some contact with most of the physicists. Mr Q was then contacted by phone for the appointment of the interview. His ideas would particularly be important in the conceptual understanding of the mechanics concepts among the Sotho group of people. He agreed. He was found by the investigator busy in the class of First year Physics. He was using a mixture of Sesotho and English in his communication with the class. Since the office in which Mr Q accommodated the investigator while he (Mr Q) was still busy with the lecture is closely adjacent to the class, the investigator "inquisitively overhead" Mr Q saying to the class: "e tla nne e tsamaye jwalo e sa kgaotse ho fihlela ho hlaha force e e fetolang ..." (rough translation: it will go continuously without stopping until some force appears which will alter the motion ...). It was interesting. He has M Sc degree from the Soviet Union. is book rack is full of books in Russian titles and writing. Mr Q did not have much time. He, however managed to complete Task 1 and Task 2 of this study and had a short interview "chat" with the investigator as follows:

I :I wished to find out from you how you understand and explain to the Sesotho speaking students these concepts which are this important to be distinguished.

Q :Ke thabile ho fumana hore ho ntse ho ena le motho ya kgathatswang ke bothata bo tswanang le bo nkgathatsang. Di-concepts tsena di ke ke tsa fetolelwa Sesothong yaba di ntse di ena le moelelo o le mong. Ka Sesotho di tla ba le meelelo e fapaneng le ena e bewang ke mechanics. Di tla fapana. (I am happy to discover that there is another person with the same difficulty like mine. The concepts cannot be translated into Sesotho and maintain the same meanings. Sesotho conceptual terms are not meaning the same ideas as the English conceptual terms mean. They are different.)

I :Ke o mametse (I am listening).

Q :Eya, Ntate, jwale ke ntse ke dumela hore mantswe a mang e tla nne e sale e le a ditjhaba feela e ntse e lemantswe a "Sothofied" (Yes, sir, I am still convinced that some words will still remain foreign but then "Sothofied" to maintain their meaning.

I :Which words for example?

Q :Kgang e tla ba teng pakeng tsa force le momentum. Jwaleka maoba o ne o re sefutho. Ke utlwa hantle hore sefutho ke momentum. Force re tla e bitsa e le matla. Ha re e tlohele e le tje? Ha re e siye lentswe leo keng e ntse e le force ka Sesotho, concept ya sala e ntse e ntse e tshwana?(There is going to be a confusion between force and momentum, like

I heard you speak about sefutho yesterday, that could mean momentum, force would be matla, why don't we leave as force even in Sesotho for the concept to maintain its meaning?)

I :O bolela hore concept e tlilo fapana ha re ka re re batla ho e fetolela Sesothong? (you mean the concept will differ if we translate it to the Sesotho term?

Q : E! e! e tlilo fapana (Yes! yes! it *will* differ). Le hoja ke eso imamele mantswe a Sesotho a mangata a tla ba le mathata (although I have not given attention as to which word should be called how, but there are numerous words which will have many difficulties to transmit the conceptual meaning).