LEARNING AND UNDERSTANDING OF THE PHYSICAL SCIENCE CONCEPTS OF FORCE, WORK AND ENERGY AT THE STANDARD SEVEN LEVEL

by

MWEZENI JAMES NELA B.Sc., H.E.D., B.Ed.

A DISSERTATION IN FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE

of

MASTER OF EDUCATION

in

THE DEPARTMENT OF CURRICULUM STUDIES

of

THE FACULTY OF EDUCATION

at

THE UNIVERSITY OF FORT HARE.

SUPERVISOR: PROF. M.A.Y. JIYA

CO-SUPERVISOR: DR Z. JIYA

DECEMBER 1997 FORT HARE, ALICE

DECLARATION

I, the undersigned hereby declare that this dissertation is the result of my own research and that the conclusions herein are my own.

M.J. Nela

DEDICATION

This work is dedicated to:

My late mother, Nongetheni Nowelile Nela for her support and encouragement throughout my school days.

My father, Siqoko Jackson Nela for supporting me until I could get the first degree though he was getting a meagre salary.

My three children, Mfundo, the first born, Noluvo, the only girl and the last born Lonwabo or Akhona.

ACKNOWLEDGEMENTS

I wish to record my indebtedness, heartfelt thanks and appreciation to the following:

Prof. M.A.Y. Jiya and Dr. Z. Jiya, my supervisor and co-supervisor, for their patience, understanding, encouraging words, their thought-provoking and fruitful discussions as well as their valuable advice, guidance and assistance.

The principals, teachers and pupils of schools visited for responding to questionnaires and interviews as well as for their co-operation and hospitality.

The Standard Seven pupils in the selected schools for their co-operation.

Ms Cheryl v.d. Merwe for the meticulous typing of the manuscript which she did with friendly co-operation and enthusiasm.

A special word of thanks goes to my wife, Phakama, my sisters and my brothers for their moral support, encouragement and understanding during the period of this study.

ABSTRACT

This study has been investigating why Black students seem to be experiencing difficulties in acquiring the accepted scientific understanding of the Physical Science concepts of force, work and energy. The instruments used to collect the empirical data for the study were student questionnaires, student interviews, lesson observations and analysis of the textbooks that are recommended for the Standard 7 level. The study was conducted in 12 schools selected randomly from schools in the King William's Town area. The sample consisted of urban, semi-urban and rural schools. Focus was on the Standard 7 students, their teachers and the textbooks recommended for the level. The analysis of the student questionnaire and interviews revealed that students showed incorrect understandings of the Physical Science concepts of force, work and energy. Some of the teachers have also been found to have an inappropriate scientific understanding of the Physical Science concepts concerned. It was also discovered that the explanations in some of the textbooks recommended for use in Standard 7 were put in a manner that could result in misconceptions at a later stage if no room is provided for the information that is to come later. The recognition of the existence of the life world meanings that are associated with the same words that are used in Physical Science is considered to be of utmost importance. It has been attempted in this study to throw more light on the fact that teachers should bring to the attention of the students that two different meanings can be attached to the same word (for example, force, work and energy), a life world meaning and a scientific meaning. It has also been recommended that open discussions on this matter should be allowed so that students could be aware of when to use a life world meaning and when to use a scientific one. The textbooks used at schools are also expected to assist in explaining the reality of the co-existence of these two worlds.

INDEX

CHAPTER 1

THE PROBLEM

1.1 INTRODUCTION

1.2 STATEMENT OF THE PROBLEM

1.3 PURPOSE OF THE STUDY

1.4 ASSUMPTIONS

1.5 POSSIBLE VALUE OF THE STUDY

1.6 GENERAL LAY OUT OF THE STUDY

CHAPTER 1

THE PROBLEM

1.1. INTRODUCTION

As a Physical Science teacher who is teaching in the secondary schools, the researcher has noticed that the majority of the students that he taught performed badly when answering questions that needed explanations that would reflect scientific understanding of certain concepts both in tests, and during end of the year examinations.

Other Physical Science teachers who teach in Black schools also pointed out the problem of students who seemed to lack scientific understanding of certain concepts when answering questions that required explanations of such concepts. These views emerged during a standard 9 Physical Science teacher in-service course attended at Hlaziya inservice centre in March 1989 by about 40 teachers from Ciskei schools. At the end of the course the in-service lecturer asked the teachers to mention some of the areas that seemed to be problematic to the students. The teachers were unanimous in saying that scientific insight/understanding of the concepts of force, work and energy that are dealt with in standard 9 seemed to be difficult to achieve on the part of the students.

The problem of lack of scientific insight when answering questions that require explanations that would reflect the scientific meaning of certain concepts such as force, work and energy was also noted by markers of the 1992 standard 10 Physical Science external examination when they gave a general evaluation of the students' performance at the end of the marking session which was held at Griffiths Mxenge College of Education. Kahn et al (1994) in their paper on "Issues and Proposals on Science Education Policy" mentioned that 76% of White students passed Physical Science examinations at the end of 1992 compared to 19% of Black students who passed a similar examination at the end of the same year. That students seem to have difficulty in capturing/grasping the scientific meaning of certain Physical Science concepts like force, work and energy might be responsible for the high failure rate of Black students in Physical Science.

Research in other countries, for example, Driver (1991), Dykstra (1994), Licht and Thijs (1990), and others have also drawn attention to this phenomenon (lack of scientific insight), ascribing it to the fact that students sometimes come to class having their own meanings about concepts to be taught at school, which meanings are sometimes different from the meaning the scientists have assigned to the concepts.

The researcher was then convinced that there is a need to investigate whether Black students do bring to class beliefs or naive ideas about certain concepts that clash with the scientific view that is introduced in a Physical Science class. Beliefs in this study are taken in the same context as Driver (1991) where she regards beliefs to mean the same thing as alternative frame-works. Driver et al (1989) define alternative frame-works as situations in which the pupils (students) have developed autonomous frame-works for conceptualising their experience of the physical world.

1.2 STATEMENT OF THE PROBLEM

Black schools have in previous years produced more students within the humanities than in Physical Science and this has been attributed to:

a) the fact that there are a few Black schools that offer Physical Science up to matric level. Most of the schools, more especially in rural areas, offer Physical Science up to standard 7, and a few offer it up to standard 8. For example, out of the 28 secondary schools in the Zwelitsha North circuit, 21 are rural schools and only 8 of the rural schools offer Physical Science up to standard 8 and above. All the urban and semi-urban schools, 7 in all, offer Physical Science at the standard 8, 9 and 10 levels. The research done by Kahn et al (1994) found that Physical Science is an unpopular subject, more especially among Black students with Physical Science taken by 17% of Black students compared to 50% of White students who take it. Kahn et al (1994) have also noted that many Black schools do not offer Physical Science.

b) a lack of facilities like laboratories even in schools that do offer Physical Science to standards 8, 9 and 10. Kahn et al (1994) say that insofar as physical resources are concerned, the majority of Black schools have no laboratories, no electricity, no running water. Kahn et al (1994) go on to state that for many students the first encounter with Physical Science apparatus is at university. At secondary school the teacher describes the experiments to them.

c) a shortage of qualified teachers to teach the subject. Out of the 17% of Black students who take Physical Science as stated in (a) above, Kahn et al (1994) noted that a few qualify with Physical Science as a possible teaching subject and few become competent Physical Science teachers. Kahn et al's research (1994) also reflects that only 5% of Black teachers have university degrees.

The new trend in the new South Africa is to structure Black education such that it aims at producing more scientifically oriented students than before in order, to bridge the imbalances of the past as well as to increase the number of Black South Africans who will be competent enough to be incorporated in industry or absorbed into other scientific spheres. In their paper Kahn et al (1994) recommend that all South African citizens should be developed into a scientifically literate nation both in the interests of the economy and for the intrinsic benefits of the individual. In order to achieve this goal, the production of Physical Science students of the required quality should be enhanced. This can only be made possible through starting first with the removal of the obstacles that impede or hinder Physical Science understanding in the classroom.

Some of the stumbling blocks to learning with understanding of Physical Science in Black schools could be the following:

i) **Teacher - Pupil Ratio**

classrooms in Black schools are overcrowded with the result that the teacher-pupil ratio is very high. There are cases where students are even 70 to 90 in a Physical Science class. For

i) **Teacher - Pupil Ratio**

Classrooms in Black schools are overcrowded with the result that the teacher-pupil ratio is very high. There are cases where students are even 70 to 90 in a Physical Science class. For example, I had a class of 74 standard 7 students to whom I had to teach the Physical Science part in 1987. My sister who was also teaching General Science in a neighbouring school was faced with teaching the Physical Science part to 98 students in one class. The problem then is how to teach a big number of students while at the same time having to improve the quality of education. Individual attention is very much impossible to achieve in such a situation.

ii) **Teacher Qualifications**

This is a big problem that is facing Black education. There are a number of unqualified or partly qualified teachers and this needs attention. Kahn et al (1994) have found that a few Black teachers are qualified to teach Physical Science, and it is commonplace to find a teacher trained for primary school teaching secondary school Science, or even a matriculant who has been unable to find a place for tertiary study. Teachers who are qualified to teach the standard 7 General Science are those teachers who have done Physical Science at least up to standard 10. Those teachers who have done Physical Science up to standard 8 are partly qualified for teaching standard 7 Physical Science, and unqualified teachers for handling standard 7 Physical Science are those teachers who have a teacher's diploma but have not done standard 8 Physical Science. People who have done standard 8 or 10 Physical Science but have not been trained to be teachers do not qualify to teach standard 7 General Science.

Black Physical Science graduates who are produced by the universities opt for industry or fields other than teaching. Since teaching does not have attractive incentives, even those Black teachers with proper Physical Science qualifications are drained out of the teaching fraternity as they are offered better pay in the private sector. Even those Physical Science graduates who are teaching in the Black schools, are made to teach or opt for teaching in the higher classes like standard 8, 9 and 10. The lower classes like standard 6 and 7 are most of the time taught by teachers who never did Physical Science in their school days. As a result they tend to concentrate on teaching the biology part of the standard 6 or 7 syllabus at the expense of the Physical Science part. The students who are products of these teachers will therefore lack the basic Physical Science knowledge and skills. This is a problem that needs special attention if Physical Science learning and understanding is to be improved.

iii) **Medium of Instruction**

The medium of instruction in Black secondary schools is English which is a second language to most Black teachers since it is not their mother tongue. Such Black teachers experience a lot of difficulty in teaching through English which is a second language to them, because they are not adequately articulate in it.

Most students too have the same problem since English is also not their mother tongue. They therefore experience problems in understanding the teacher and also what they read from the textbooks. The process of acquiring, storing, transmitting and generating knowledge is, as a result, not easy.

Kahn et al (1994) feel that for a second language speaker, the thorny problem of medium of instruction needs to be addressed in order to decrease the learner's feeling of alienation from Physical Science.

iv) **Lack of continuity between the cultural world of the student's family and that of the school**

One of the major problems that hinder meaningful learning has been identified by researchers such as Driver (1991), Howe (1996), and others, as the lack of continuity between the cultural world of the family of the student and that of the school. Research studies have revealed that students bring to class naive ideas or beliefs about certain concepts that sometimes differ from the scientific understanding of the concepts concerned.

v) **Academic nature of Science**

As far as Kahn et al (1994) are concerned a widespread view of Physical Science held by students in South African schooling is that Physical Science is largely academic, with little if any evident connection with technology, industry or everyday life. Kahn et al (1994) also see the syllabus as being heavily dominated by examinations which stress factual recall or application of standard algorithms rather than encourage problem solving, creativity and conceptual thinking.

All the factors discussed in 1.2 have served as a basis for this study.

1.3 PURPOSE OF THE STUDY

This study must be seen as an attempt by the researcher to:

a) identify the preconceptions and misconceptions that Black standard 7 students have about force, work and energy. The context in which the term 'preconception' is used in this study is as indicated/suggested in Jiya (1990) as being a collection of factual and predicted outcomes based on prior specific actions or schema, found in a person's mind which are used by that person to deal with some particular information outside that person's mind. Misconception on the other hand is a term used in studies when pupils (students) have been exposed to formal models or theories and have assimilated them incorrectly (Driver, 1989).

b) establish whether the teachers are aware of the students' preconceptions and misconceptions or are themselves having the same problem, and what approach or method they can use to develop the students' ideas towards a more widely accepted and applicable scientific view.

c) analyze the textbooks used at this level to find out whether they do not exacerbate inappropriate / incorrect conceptions that students may have with regard to the concepts of force, work and energy or whether they are explanatory enough to develop the accepted understanding of the scientific concepts in question.

d) to make recommendations regarding measures that can be taken to combat the problem.

1.4 ASSUMPTIONS

The following assumptions are made to establish a basis of the procedure for this investigation.

a) The students will respond without bias to questions in the questionnaires that are administered to them.

b) The observed teachers would be teaching in exactly the same manner as when there was nobody observing.

c) The schools selected by simple random sampling are representative of all Black secondary schools in the King William's Town area.

1.5 POSSIBLE VALUE OF THE STUDY

The researcher strongly felt that it would be educationally justifiable if the problems encountered by students with regard to scientific understanding of Physical Science concepts and possible reasons thereof could be brought to light.

Having achieved the above goal it is hoped that the findings of this study:

a) might bring about general awareness of the preconceptions and misconceptions that hinder the scientific understanding of Physical Science concepts by students in Black secondary schools.

b) might conscientise teachers to take note of conceptions that students bring to class from their every day life world and misconceptions that they may inherit during the course of the teaching and learning process. This might then make the teachers improve their teaching strategies or seek assistance to alleviate the problem.

c) might inspire education planners and administrators to regard conceptions that students bring to Physical Science classes as a problem area and work on means of solving this.

1.6 GENERAL LAYOUT OF THE STUDY

In this chapter, the problem was stated, salient aspects were delimited and the possible value of the study was outlined. Chapter 2 will examine the important contributions already made by the research on topics of a similar nature.

Chapter 3 will be devoted to the research design and methodology to be followed in this study.

Chapter 4 will reflect (i) the analysis of the student questionnaire results and presentation of the accompanying findings as well as (ii) the analysis and presentation of the interview findings, (iii) lesson observation findings and (iv) textbook analysis findings.

Chapter 5, the concluding chapter, will contain further analysis and categorization of the main findings and conclusions, and will also carry the main recommendations of the study as well as suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

2.1. INTRODUCTION

Yager and Lutz (1995) assert that many adults shun science, even if they liked it as children. They go on to say that more than half the students in American elementary schools like science, but by the time students reach high school, the number of students who like Science decreases. According to them students who choose professional science, medicine, or engineering careers represent less than 1% of the total who graduate in a given high school class. The word science will be regarded as referring to Physical Science in the present study.

As underlying reasons for the above state of affairs Yager and Lutz (1995) highlight the following observations made by cognitive researchers:

a) The science learned in school is not internalised and therefore knowledge is not really learned (gained).

b) The best students may perform well on tests and advance to the next academic level, but the science explanations they internalise and believe are idiosyncratic interpretations of the real world based upon their own experiences.

c) There is often a discrepancy between school science and 'real world science'. (Real world science refers to the interpretation or explanation given to science related events in everyday life, like, saying that what keeps an object moving is an inherent force inside the object).

d) The real world experience wins virtually every time over the science of textbooks, classrooms, laboratories and school generally. (This implies that even after reading science textbooks and performing experiments to reinforce a scientific phenomenon that has been taught at school, some of the students are found to interpret or explain the scientific event in terms of how it is perceived in everyday life).

Kahn et al (1994) made the following findings as far as the status of South African Science Education is concerned.

a) Physical Science is an unpopular subject taken by but 50% of White school children, while figures for Blacks are around 17%.

b) At the end of 1992, 18579 candidates sat for the Department of Education and Culture (White) matric Physical Science examination and 14209, that is 76%, passed. On the other hand, out of 66166 candidates who wrote the Department of Education and Training (Black) matric Physical Science examination only 1294 (19%) made it.

It is statements and facts like the ones quoted above that have prompted the present researcher to conduct the investigation of the problems encountered by Black students in the learning and understanding of school science.

Having identified the problems that Black students might have in learning and understanding Physical Science concepts, the researcher decided to read more on research related to the envisaged study in order to familiarise himself with findings of such studies.

2.2. NATURE AND PHILOSOPHY OF SCIENCE

By way of background information on the philosophy of Science Education the researcher is going to refer to the Piagetian and Vygotskian perspectives of Science Education as reflected in the research study done by Howe (1996).

2.2.1. Review of the Piagetian Perspective

For the past three decades Piagetian theory, as understood in the United States, has been used as the basis for widely accepted ideas of what constitutes good instructional practice in elementary science (Howe, 1996). Three elements of this theory have been particularly influential as far as Howe is concerned.

a) The first element is the focus on internally driven mental activity of the individual child. This has led to the hypothesis-testing approach to instruction in which the goal is for the student to discover concepts as a consequence of applying logical thought to the results of his or her own interaction with objects and phenomena encountered in the class room or every day experience.

b) The second element is the theory that cognitive development proceeds in stages that are universal and predictable. This has been used as the basis for designing curricula that take into account the developmental level of students when deciding which science concepts are appropriate for students at the various grade levels. Neither previous experience, the social context, nor individual interests are thought to override the primacy of the child's cognitive stage in determining what can be learned, and should be taught, within a rather narrow age range.

c) The third aspect of Piagetian theory that has been most influential in Science Education is constructivism. At the most basic level this is the belief that we can only know the world through mental activity that organizes or transforms our perceptions, that is, that each individual constructs knowledge and meaning for himself or herself.

2.2.2. Review of the Vygotskian Perspective

Vygotsky, a Russian psychologist, developed what he called a working hypothesis of the relation of instruction to development by considering how children acquire scientific concepts in subjects taught at school. He was interested in the relationship between the concepts formed from a child's experience and independent thinking, which he called everyday concepts, to those learned at school, which he called scientific concepts, (Howe, 1996).

As far as Vygotsky is concerned everyday concepts are based on particular instances and are not part of a coherent system of thought while scientific concepts are presented and learned as part of a system of relationships. Scientific concepts, as defined by Vygotsky, are always part of a system of relationships, and, as such, are built up over time (Howe, 1996).

part of a system of relationships. Scientific concepts, as defined by Vygotsky, are always part of a system of relationships, and, as such, are built up over time (Howe, 1996).

According to Howe, Vygotsky (1978) asserts that from the very first days of the child's development, his activities acquire a meaning of their own in a system of social behaviour and, being directed towards a definite purpose are refracted through the prism of the child's environment. Vygotsky further asserts that the path from child to object passes through another person, and the complete human structure is the product of a development process deeply rooted in the links between individual life and social history. Vygotsky saw scientific concepts as having meaning through their relationships with one another and being transmitted through the culture and social institutions of society rather than evolving naturally in the course of development of individual learners (Driver et al, 1994).

2.2.3. **Comparison of Vygotsky's and Piaget's Theories of Concept Development**

Since Piagetian theory has provided the dominant framework for research and curriculum development in Science Education for almost three decades, any alternative theory will inevitably be compared to it by Science Educators. It should be remembered, when this comparison is made, that Vygotsky was specifically interested in improving instruction in school while Piaget's research did not directly address the influence or effect of schooling. Piaget, in fact, purposely sought to study the development of concepts that arose spontaneously rather than those that were taught at school. Nevertheless, important practical implications for Science Education emerge from comparison of the two theoretical positions (Howe, 1996).

a) Piagetian thought is characterised by the view that the driving force in development is internal while Vygotskian thought is characterised by the view that the driving force is external.

b) For Piaget maturation was the central factor in development while for Vygotsky the social world was central.

c) Vygotsky's view was that knowledge develops through appropriation of the culture, through social interaction between the child and others more competent. Piaget's view in this regard is that the mechanisms for development reside within the child.

d) Piaget recognised social-linguistic transmission as a factor in the development of knowledge, but only if cognitive structures necessary for assimilation were already present, and argued that logical concepts grow within the child's mind without outside intervention, while Vygotsky on the other hand argued that concepts could not grow without social interaction.

Howe's view is that merging of Piaget's constructivist view and Vygotsky's sociocultural view of knowledge acquisition may obscure the theoretical differences between the two ideologists, and

a) reduce constructivism to an idea that every one can accept, and

b) provide a frame-work within which to co-ordinate sociological and psychological perspectives of classroom life and serve to free research of narrow theoretical constraints.

A combination of the two perspectives, Vygotsky and Piaget's perspectives, is a basis for the present researcher's study. The fact that the students sometimes come to class with preconceived ideas about some of the concepts that are taught at school which they have gathered from social institutions, should not be discarded. This information should be taken as a stepping stone or basis for the construction of scientific knowledge. Though the everyday life meaning may not be directly related to the scientific meaning that is introduced at school, revisiting the everyday life world meaning of the concept concerned might level the road for a better assimilation of the scientific meaning.

The researcher is of the opinion that non-denial of the co-existence of the social and scientific institutions might be a solution to the problem that some of the students seem to have in assimilating the meaning given by scientists to concepts used in everyday life, as students will be able to differentiate between the everyday life meaning and the scientific meaning or associate the two. The recognition of the co-existence of the social and scientific institutions is what the present study intends to emphasize.

2.3. <u>SCHOOL SCIENCE TEACHING AND LEARNING PROBLEMS</u>

Dykstra et al. (1989) tate that studies have found that students begin formal physics education with a system of physical conceptions that differ in deeply systematic ways from those of the physicist and present a significant obstacle to learning physics. They go on to say that conceptions are not addressed by standard instruction, either in the physics classroom or in introductory physics textbooks. Traditional physics instruction, embodied in the traditional physics textbook presents a physicist's understanding of the world. Students have difficulty in applying the physics understanding to qualitative discussions of physics situations and problem solving.

In addition Yager and Lutz (1995) state that research has shown that cognitive psychologists are united in their observations that high school graduates, including college students, have naive theories or misconceptions about the real world. They have further noted that students retain these views even when they have successfully completed advanced courses that encompass scientific concepts and theories which make cognitive researchers conclude that the science learned at school is not internalised and knowledge is not really learned.

Bybee (1994) points out that there is a difference between teaching scientific information and developing student understanding of science concepts. He accuses school science programmes, textbooks and teachers of having emphasised the knowledge of information and facts.

Yager and Lutz (1995) cited the following problems with regard to school Science teaching that have to be addressed if Science understanding is to be promoted.

a) More than 90% of all Science teachers use textbooks more than 90% of the time. They use the textbook as a source of information, and also as a source of questions to be used in quizzes and examinations as well as questions asked by the teachers during their lessons. Creative input from the students is ignored. (Hence the researcher's review of textbooks as possible sources of science misconceptions).

b) The science information presented in schools appears to have little impact on the daily lives of the students. Applications of concepts (ideas) to students and/or society in general are omitted.

c) Teachers view themselves as authoritative sources of the information students must learn. They rarely admit to not knowing and thereby restrict students to a rigid course outline.

d) Evaluation is based on the mastering of vocabulary and recalling of information from textbooks and lectures, rather than on an assessment of whether or not students comprehend and can apply the knowledge they seem to have gained.

As far as Dykstra et al (1992) and Yager and Lutz (1995) are concerned the methods and approaches of the physicist only make sense in the context of the physicist's conceptualisation of the world. Simply presenting students with the logical arguments of Newtonian mechanics when they solve problems, for example, does not encourage conceptual learning because such reasoning makes little sense in the context of their own beliefs.

If Physical Science instruction is to be effective, it must encourage the kind of learning that leads to conceptual understanding. Current physics instruction or teaching, therefore, must acknowledge that students' beliefs about how the world works are strongly held because their conceptual understanding has been constructed over many years of experiencing the everyday world. Physics instructors and Physical Science teachers are thus faced not just with getting students to construct new knowledge, but with getting them to construct this knowledge in the face of strongly held beliefs.

2.4. CONCEPTIONS ABOUT FORCE, WORK AND ENERGY

2.4.1 Students' Conceptions

Driver (1991) states that a child develops beliefs about the things that happen in his/her surroundings from the very earliest days in his or her life. She cites an example where a child releases an object from his or her hand which subsequently falls to the ground, and when repeating the process a pattern emerges. She also quotes a case where a child pushes a ball and it goes on rolling across the floor. She then concludes that in this way sets of expectations are established which enable the child to begin to make predictions. These experiences are initially, isolated and independent of each other, but as the child grows older, all his/her experiences of pushing, pulling, lifting, throwing, feeling and seeing things stimulate the development of more generalised sets of expectations and the ability to make predictions about a progressively wide range of abilities. Driver's experience has shown her that in some cases the beliefs or intuitions that children have about things happening are strongly held and may differ from the accepted theories which science teaching aims to communicate. In the present study Osborne's meaning of the term 'intuition' as reflected in Osborne and Freyberg (1992) is going to be followed. Osborne regards intuitive ideas (intuitions) as ideals that students have already developed before coming near a science classroom.

Preece (1984) believes that it is in mechanics where preconceptions are less affected by instruction.

2.4.1.1. **Student's Ideas about Force**

According to Licht and Thijs (1990) students' intuitive ideas on "force" create problems with the school subject of mechanics, and conceptual difficulties in situations with force and motion appear to persist over a range of educational levels.

As far as Dykstra et al (1992) are concerned students seem to extend their class of elastic objects from those which visibly deform to include at least some objects which do not visibly deform in order to explain the origin of an upward force from a table that acts on a book that is placed on the table. Dykstra et al (1992) made the following observations with regard to forces that act on a book that is placed on a table.

a) Many students do not think of the surface on which a book rests as exerting a force on that book. To them "The table under the book is just in the way".

b) Students at first, indicate in discussions that it seems impossible that something like a table is actually exerting a force when it is merely functioning as a "support". Supports in these students' alternative conceptual frame-works do not exert forces.

Thijs (1992) supports the above observation when he says that in situations of objects at rest, many students do not indicate the normal force. He is of the opinion that students find it difficult to accept that a passive object like a table does indeed exert a force. For example, in the students' perception, a person standing on a table will only experience a downward force of gravity, and not an upward force from the table.

Osborne and Freyberg (1992) performed a research study as part of the Learning in Science Projects at the University of Surrey. They used interview cards to interview 40 pupils (students) aged between 7 and 20 on force and motion.

They obtained the following findings about children's association of force and motion.

a) Friction is associated, in many pupils' (students') minds, with wear, the generation of heat and rubbing, and in their thinking, two surfaces which are not in relative motion do not involve frictional forces. They regard a stationary box on a slope as just being stuck.

b) Gravity increases with height above the earth's surface. Since they have learned that objects dropped from a greater height cause more damage than those dropping a short distance because they fall faster, they are of the opinion that more gravity must be acting on them.

c) Children have a strongly held view that objects move forward because there is "something" in them keeping them moving and they ascribe the label force to this "something" in them keeping them moving and they ascribe the label force to this something, instead of momentum, which is not a force.

Essential misconceptions in the subject area of force and motion as highlighted by Thijs (1992), are borne from the fact that in everyday life students generally associate a continuing motion with continuing force. This leads to the following misconceptions:

a) In a rest situation, no forces (or only the force of gravity) are (is) present.

b) When an object moves at a constant speed, a force is acting in the direction of motion, which is necessary to overcome counter forces.

c) A force exerted on an object is imparted to that object as an acquired impetus (inherent force).

d) The impetus of a moving body will gradually weaken. Hynd et al (1994) support this view when they say that many students intuitively believe that a moving object has had an internal force implanted in it that has caused its motion, and that this internal force dissipates over time causing the object to come to a stop.

e) An increasing velocity requires an increasing force in the direction of motion.

2.4.1.2. **Students' Conceptions of Energy**

Trumper (1990) has researched and found that:

a) children's early alternative concepts about energy appear to arise from a context which is inappropriate for school science, but which is valid and valuable in their everyday world. Many words in science, like energy, are used differently in everyday language.

b) often a student can listen to, or read a science statement, and assimilate it by using everyday interpretation of the word. The interpretation may not be the one intended by the teacher, for example, the following excerpt recounts a ninth grader's comparison of a person and a car, in terms of energy.

"A car which is filled with petrol and then travels away is like a human being eating. Food supplies persons with energy and force so that they can move. In the same way, petrol supplies the car with energy and force so that it can travel. In short: food is energy for human beings and petrol is energy for cars" (Trumper, 1990).

Kruger (1990) is of the opinion that the word energy has acquired a wealth of meaning from social usage, and that is why there is a need for scientific clarity if there is to be any real progress in the teaching of energy. Kruger further asserts that the development of children's notions of energy will require confident mentors who know the pitfalls in the life-world views of children, who can effectively plan appropriate experiences for children and fruitful questions concerning them, (such that appropriate notions are cultivated).

One of the students used in the research study by Driver (1991) was trying to explain his reasoning behind the discussion he gave for the results of an experiment that he was part of, when he made the following illustration:

He picked up two marbles and held one up higher than the other and explained as follows:

> "This is farther up and gravity is pulling it down harder. I mean the gravity is still the same but it turns out it is pulling harder the further away. The higher it gets the more effect gravity will have on it because, like if you just stood over there and someone dropped a pebble on him it would just sting him, it wouldn't hurt him. But like if I dropped it from an aeroplane it would be accelerating faster and faster and when it hit someone on the head it would kill him" (Driver, 1991)

In this quotation, the student's idea of gravity or weight appears to encompass the notion of gravitational potential energy. It seems likely then that other students too might be confusing gravity with gravitational potential energy.

2.4.1.3 <u>Ideas about the Concept Work</u>

According to Millar (1989), the layman's idea and the scientist's understanding of the concept of work differ in some instances. He goes on to say that in everyday talk, work can mean quite a lot of different things: digging the garden, doing washing, writing an answer to a physics problem, or even sitting reading a textbook, whereas in physics, work is done on something when a force makes it move. The force considered should be in the same direction as motion. Scholtz et al (1989) are of the same opinion when they say that in science, work has a somewhat different meaning to what it has in everyday life.

According to Millar (1989), the physicist and the man in the street do not always refer to the same thing when they speak of work. To drive the point home he cites the following cases:

a) If one carries a heavy object around all day one may feel that he or she has done a great amount of work, but as long as one walks at a constant speed and on a level surface, one has done no work on the object in the scientific sense of the term, in spite of his or her fatigue. The force applied on the object is upward and therefore at right angles to the direction of motion.

b) By contrast if one were to climb a hill part of his or her motion would be upward, in the same direction as the force exerted on the object, so he or she would be doing work.

c) Even if one can sweat or strain a muscle trying to open a peanut butter bottle lid without success, he or she will have done no work (in the scientific context).

d) If one applies a force of 800N on a rock without moving it, he or she will have done no work on the rock. Yet if one lifts up a piece of paper, one has done work on the paper.

2.4.2. **Teachers' Conceptions about Force and Energy**

The following comments which were made by 2 teachers who were interviewed by Osborne as reflected in Osborne and Freyberg (1992), illustrate that some teachers do have difficulties in handling or teaching the concepts of force and energy to younger students.

First teacher : "I feel I need time and resource materials from a physics-minded person to help with that particular topic (force and motion). Especially at the 13 year old level, that they would understand it and enjoy it".

Second teacher: "When it comes to teaching things like force and energy they (teachers) get them all confused. Many teachers just throw the section (of work) at them in a week or two weeks, and the kids (13 year olds) get rather muddled because the presentation was muddled".

An investigation on primary teachers' understanding of the concepts of force and energy was done by Kruger et al (1992) in England. The sample was composed of English Primary teachers who were responsible for teaching Physical Science to their classes. Many of the teachers, in addition, were responsible for planning and co-ordinating Physical Science teaching through the whole school. The teachers were required to respond to questionnaires on force and energy. The findings of this research study were presented as follows:

2.4.2.1 **Findings from the Forces Questionnaire**

a) Kruger (1992) established that many teachers did not recognise that a table or the ground is considered by scientists to exert an upwards force on objects.

b) The status of friction as a force was not understood by 67% of the teachers.

c) A substantial number (40%) of the teachers were unsure of the status of weight as a force or denied that it was a force, while over 50% of the sample did not identify weight with gravity.

d) As many as 91% agreed with statements about those instances which implied a belief in a naive impetus theory, that is, the view that a moving body possesses something intrinsic in its motion that keeps it going.

2.4.2.2 **Findings from the Energy Questionnaire**

As far as the energy questionnaire is concerned Kruger (1992) established that there was (were):

a) uncertainty about the energy associated with an object as it moves upwards, reaches the top of its flight, and then falls.

b) an absence among many teachers of any notion of gravitational potential energy and an association of energy with motion other than position.

c) substantial numbers of responses that contradicted the principle of conservation of energy.

2.5. THE ROLE OF THE TEACHER IN SCIENCE LEARNING

A teacher who was the Head of Science at a school interviewed by Bell and Osborne uttered the following statement to indicate the importance of the teacher to the student :

> "The most important thing for students, particularly of average ability is their relationship with the teacher. Ask them what they think of science and you invariably get a comment back on what they think of the teacher" (Osborne & Freyberg, 1992).

Osborne and Freyberg (1992) agree that:

> "To most children the science teacher is the only 'scientist' they know - certainly the only 'scientist' who knows them".

Dykstra (1992) found that there is often a severe problem of lack of communication between the teacher and pupils. When two people communicate, what passes between them are the words and gestures they use to attempt to convey meaning. So a teacher has some ideas which he or she hopes to convey by putting them into words, diagrams or symbols. The child may take note of the words, and so on, but from these he or she has to build up a meaning for them, that is, words, diagrams or symbols. There is clearly a strong possibility that this meaning created by the child is not the meaning intended by the teacher. This possibility is very high if the language used by the teacher or work-card, is not familiar to the child.

Various things may happen. The child may ignore what the teacher is saying, or the teacher may ignore what the child is saying.

Yager and Lutz (1995) have also discovered that

a) Traditionally, science has been taught as though all students could and should become practicing scientists.

b) Teachers give special attention and praise to outstanding students in the traditional school setting which may have the following negative results:

   i) Young children, ever sensitive to unfairness or perceived neglect, may interpret praise of others' success as a statement about their own inadequacies.

   ii) Those who are not naturally gifted in science may be discouraged when only those who are gifted receive praise.

Yager and Lutz (1995)'s view is that

a) Not all students in Science classes end up being scientists, but they all have the right to a good Science Education.

b) Students with actual talent deserve praise, but equally so do those who simply go to their studies with enthusiasm and creativity.

2.5.1 <u>Language related problems</u>

Bell and Freyberg as reflected in Osborne and Freyberg (1992) have identified the following problems involving the language used in the science classroom.

a) If the teacher's language includes words unfamiliar to the pupils, which are not explained in the pupil's language, comprehension of what is being said will not occur. Pupils simply fail to construct meanings from the teacher's flow of words.

b) Where the teacher's own concepts are inadequate there is unfortunately a greater likelihood that the teacher will consciously or subconsciously try to obscure his or her lack of understanding by the use of technical language, whether it be verbalised, written on the board, or referred from the textbooks.

c) Irrespective of the teachers' scientific understandings, their use of unfamiliar language allows them to be in control of the situation, provided they can always maintain a certain level of pupil interest in what is gong on. Bell and Freyberg feel that pupils who attempt to interact with the teacher using their more hesitant and less eloquent expressions are automatically at a disadvantage and such attempts can be easily devalued, and even ignored by teachers.

d) When the language of the teacher involves familiar words used with specialist meanings in the science classroom, particular difficulties can occur because both pupil and teacher may be unaware of, or more importantly unable to identify, the source of the problem. Words like ‘animal’ and ‘living’ (like ‘force’, ‘work’ and energy’ in the present study), each have two or more subtly different meanings. The example ‘animals are living things’ is a statement which could be said by any teacher, agreed with by all pupils, but could result in (students) pupils constructing a widely different range of meanings depending on whether they are using a scientific meaning of ‘animal’ and ‘living’, or a meaning used in everyday language.

2.5.2 **What is expected of a Science teacher?**

Appleton (1993) feels that a necessary change would be for the teacher to consider the preconceptions of the children they are going to teach before they select activities.

Wildy and Wallace (1995) strongly believe that good science teachers are those who teach for good understanding, who use students' ideas about science to guide lessons, who provide experiences to test and challenge those ideas to help students arrive at a more sophisticated understanding and whose classrooms are learner centred places where group discussions, exploration and problem solving, are common place. They further go on to describe good science teachers as those teachers who help students connect science with real world experiences to build understanding out of their prior knowledge.

As far as they are concerned learning, then, occurs as students try to make sense of what is taught by trying to fit it in with their own experience. Teachers in turn need to have a clear idea of what students already know and understand so that they can engage students in activities that help them construct new meanings. Good science teachers, therefore, should understand the cultural context of the school, have a clear consistent view of the subject matter, build a learning community of trust, and adapt the curriculum to accommodate the knowledge, needs and aspirations of the students.

Benchop and Ottevanger (1995) assert that for successful learning to be achieved, the teacher-centred approach with the teacher in full control of the learning process should be a thing of the past. Learners should be responsible for their own learning and the teacher should be a facilitator of the learning process. To substantiate their point of view they referred to the Namibian Ministry of Education and Culture 1993 Curriculum which is based on a learner centred approach. The underlying aspects of this approach are:

a) the starting point is the learners' existing knowledge, skills and understanding derived from previous experience in and out of school.

b) the natural curiosity and eagerness of all young people to learn, to investigate and make sense of the widening world must be catered for by challenging and meaningful tasks.

c) the learners' perspective needs to be appreciated and considered in the work of the school.

d) learners should be empowered to think and take responsibility not only for their own, but for one another's learning and total development.

e) the learners should be involved as partners in, rather than receivers of, educational growth.

2.6. TEXTBOOK CONTRIBUTION TOWARDS UNDERSTANDING SCIENCE

Of all the material resources commonly at hand, by far the most common and most important is the textbooks or textbook series in use in a school. In fact in many cases this aid becomes the controlling influence or determining factor for content, strategy, and approach (Scopes, 1973).

Scopes (1973) regards a good textbook to be one which will do the following things:

a) provide most of the content. A choice of supplementary material must be left to the teacher, this choice being dependent on the abilities and interests of the students concerned.

b) present topics in a manner that builds understanding. In this respect one uses the expertise and experience of the writer or writers which often is very considerable.

c) provide exercises, experiences, directions for attaining mastery through practice, review, application and thought provoking questions.

d) provide means of independent study.

e) make provision for individual differences.

f) act as a compact reference book.

g) provide a basis for achievement testing.

Scopes (1973) sums up by saying:

> "In short, a good textbook provides a basis for classroom instruction, a sort of launching pad from which the class may take off for further work or exploration - either corporately under the guidance of the teacher, or individually when particular interests are aroused" (Scopes, 1973).

2.6.1. Findings from Textbook Analysis

Strube (1988) of the South Australian College of Education performed an analysis of textbooks that were intended for use in high school Physical Science classes. These textbooks ranged over a period of 84 years from 1900 to 1984. Extracts from the textbooks were scrutinised and, to enable a realistic comparison to be made, all the extracts were taken from the treatment of the same topics, namely, energy and fields. The main objective of the study was to look at the traditional language of Physical Science.

Having analyzed the extracts, Strube (1988) made the following conclusions and recommendations.

2.6.1.1. Conclusions

a) The reader was not offered justification for sequence, for approach, for emphasis attached to particular concepts, for value and purpose of thinking/doing/believing one way or another.

b) The authors never expressed any doubts about the ability of language to correctly convey the scientific understanding of things.

c) Related to the above, the authors never discussed the underlying reality of their concepts even when they discuss heuristic constructs such as analogues.

d) The textbook writers have never felt it to be important to take the student into the reality of the scientists' working world. Science as profession, done by people for a living is not portrayed in the texts.

2.6.1.2. **Recommendations**

As a form of recommendations Strube (1988) listed factors to be considered in order to classify a textbook as a good one.

He regards a good textbook as one that:

a) provides for both information and instruction.

b) gives explanations appropriate to the nature of explanation in science and makes explicit the reasons why they are uniquely scientific.

c) uses a language of enquiry that would assist the reader in following arguments, make crucial connections between the world and the textbook, and demonstrates the human and scientific purposes behind both statements and purposes.

d) contains a wide range of instructional prose structures as possible.

e) should be as concerned with the needs of the reader as with examinations and societal influences.

f) should be concerned with fostering an interchange between reader and author that would encourage learning through reading, rather than confining its purpose to informing.

Yager and Lutz (1995)'s paper on STS to enhance Total Curriculum revealed that:

a) at present, most teachers argue that they are aiding students in understanding Science by reviewing the information found in standard textbooks.

b) textbooks present content without personally relevant context, and focus on the structure of the different disciplines and on the generalisations currently accepted by the professionals. Often these generalisations are abstract, and they are important and attractive only to practicing scientists.

c) it is rare for textbooks to attempt to consider generalities that are useful to, or important in the daily lives of real people. For example, the coefficient of friction is taught as a concept important in itself. It would be much memorable if students could be taught that the co-efficient of friction is important as the physical force that prevents cars from being flung off the road when they curve onto a highway ramp to enter or exit a highway.

Groves (1995) performed a textbook vocabulary load analysis where he found out that the amount of new vocabulary terms presented in such textbooks was higher than recommended for junior high and high school foreign language courses..

From this discussion it seems that textbooks need to be revised in order to keep abreast of developments within the scientific field, that is, textbook authors should accommodate recent innovations in Physical Science so as to be able to contribute effectively to Physical Science learning.

2.7 THE CONSTRUCTIVIST APPROACH AS A TOOL FOR REDUCING STUDENT MISCONCEPTIONS

A constructivist approach assumes the existence of learners' conceptual schemata and the active application of these in responding to and making sense of new situations. (Trumper, 1992).

Driver (1981) as quoted by Treagust (1991) describes five strategies that can be used with success in constructivism as follows:

a) helping students in expressing their own ideas;

b) providing experiences with the students prior knowledge;

c) allowing time to conceptualise these experiences;

d) allowing time to use these concepts, and finally;

e) providing a supportive learning environment.

Treagust (1991) says that:

a) a constructive frame-work must determine the students knowledge for that particular topic so that appropriate student activities can be designed.

b) As students develop their own concepts during group discussions and class discussions, teachers need to act more in the role of those who facilitate learning.

Treagust feels that using this frame-work, science curricula may more effectively ensure that science is more applicable, understandable, and enjoyable for all students.

Learning science, therefore, is seen to involve more than the individual making sense of his or her personal experiences, but also being initiated into the ways of seeing that which has been established and found to be fruitful by the scientific community (Driver, 1989).

Thijs (1992) of the faculty of Physics and Astronomy at the Free University in the Netherlands conducted a study using constructivist principles to evaluate the effectiveness of the approach in reducing misconceptions on forces on objects at rest and forces on objects in motion.

A series of ten lessons were conducted by four teachers in seven classes of Form 3 (Grade 9 equivalent) students at a secondary school in the Netherlands in 1990.
The most important characteristics of the lesson series were:

a) making students aware of their own ideas and other conflict opinions in the class;

b) the introduction of force as being the cause of change of momentum; and

c) the use of various practical activities to establish a coherent description of the situation of rest and motion in terms of acting forces.

His assessment of the whole course is that it helped to improve the qualitative understanding of the concept of force by Form 3 students. He regards the lessons as having been effective in changing students' ideas towards scientifically appropriate conceptions, in particular, in regard to forces in rest situations and frictional forces, but was less effective in remedying the impetus idea.

2.8 **CONCLUSION**

In order to produce scientifically literate people, Science Educators should have a clear vision of what science literacy actually is. Yager and Lutz (1995) argued that scientific literacy is a part of cultural literacy because a truly literate person in today's world must understand the use of science and technology. In order to achieve this Yager and Lutz (1995) refer to the goals of the Project Synthesis. These goals called:

a) for a formulation of Science Education so that students are prepared to participate in discussions in a technological society.

b) for a reorganisation of the curriculum beyond the limitations imposed by a single discipline focus which in turn implies change in teacher preparation and certification.

c) for new materials, new ways of translating research into practice, and new ways of evaluating students that include the effective and creative aspects of science.

d) finally, for better support systems for exemplary teaching.

Science programmes that address these goals should be science for meeting personal needs, science for resolving current social issues, science that assists in career choice, and science that prepares students for further study. Students who are fortunate to experience science as envisaged by the Project Synthesis will be scientifically literate (Baker, 1989).

As they are striving towards achieving the Project Synthesis goals, Science Educators should not lose sight of the fact that students bring to science classes pre-conceived ideas or beliefs that are embedded in their culture, and which are true in their own setting. In the process of making students scientifically literate, Science Educators should not divorce students from their beliefs, but should show them that the two worlds, namely, everyday life and scientific worlds, move parallel to each other.

To substantiate the statement the researcher would like to refer the reader to Trumper (1990) when he says that it is neither possible nor desirable to remove the intuitive ideas and replace them with the accepted scientific concept. To emphasize this notion further, Trumper quotes Solomons (1983) who says:

> "Such socialised knowledge cannot ever, by its very nature, be extinguished. Whether or not our pupils become successful in science, they must never lose the ability to communicate. It would indeed be a poor return for our science lessons if they could no longer comprehend remarks like 'wool is warm' or 'we are using up all our energy'. What we are asking from our pupils, then, is that they should be able to think in two different domains of knowledge and to be capable of distinguishing between them" (Solomons, 1983).

The researcher's line of research is based on the above quotation and mainly on the research work done by Driver (1991), Kruger et al (1992), Osborne and Freyberg (1992) and Thijs (1992).

Having reviewed the literature related with the present investigation, the researcher will, in Chapter 3, discuss how the present research study has been designed to meet the goal of the investigation, and what procedure has been followed.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1. INTRODUCTION

In the previous chapter an overview of research done on student preconceptions, misconceptions and alternative frame-works has been given. It is the intention of the researcher in this chapter to describe the structuring of the information-gathering instruments that were used in the investigation of the problems that standard 7 students have with understanding the Physical Science concepts of force, work and energy. The construction of the information-gathering tools will also be discussed briefly.

There are various possible options open to an investigator for the purpose of gathering information needed for a particular research project. Some of these methods are observation, structured and unstructured questionnaires and structured and unstructured interviews. The present investigator selected a structured questionnaire, structured interview, lesson observation and the analysis of textbooks used at the standard 7 level as instruments for gathering the desired information.

As the present study centres around the learning problems of students, schools constitute the main area approached for information.

3.2 BACKGROUND OF THE STUDY

From the researcher's experience as a standard 8,9 and 10 Physical Science teacher at schools in the King William's Town area, some students seemed generally not able to answer Physical Science questions in an acceptable manner after they had been taught. The aim of the research was to investigate why.

The problems experienced by students in acquiring an acceptable scientific understanding of the Physical Science concepts of force, work and energy could fall into one or more of the following categories:

a) The student could be coming to the Physical Science class with his or her own understanding of the concepts as encountered at home or in everyday life This understanding could be different from the accepted scientific understanding of the concept, and unless properly attended to, this problem might affect the student's scientific understanding of the Physical Science concepts.

b) Students sometimes end up understanding the concepts taught in a completely different manner to the one presented to them by the teacher, that is, they sometimes end up giving a distorted meaning to the concepts compared to the scientifically accepted version.

c) Teachers too could be having scientifically unacceptable understandings of some of the Physical Science concepts and may therefore transfer their misdirected scientific version or versions to the students during the course of the lesson.

d) The teachers might not be aware of the fact that students could come to Physical Science classes with naive ideas or may end up understanding the concepts taught with a totally different meaning compared to the scientifically accepted one. As a result of their ignorance of this fact, the teachers might therefore not cater for students' prior beliefs with regard to the concepts concerned as well as meanings that are completely different from the scientifically accepted ones that students assign to the concepts after they have been taught.

e) The prescribed textbooks used by the students may not be catering for preconceptions and misconceptions that the students might have. If so the authors of the textbooks would then have failed to alleviate the problem of having an unaccepted scientific understanding of the Physical Science concepts by the students, since the teachers and students depend on the textbook as a source of information. The language used in the textbooks might also have a contributing factor to the students' misconceptions if it is a second language to them.

3.3. <u>THE SAMPLE AND HOW IT WAS SELECTED</u>

The sample for this study consisted of standard 7 students in 12 junior and senior secondary schools around King William's Town. The random sample was selected in a manner which would ensure that the respondents constituted a representative sample. The schools selected were rural, semi-urban and urban.

The following schools were selected for the sample:

	School	Type of Area where Situated
1.	School A	Rural
2.	School B	Rural
3.	School C	Urban
4.	School D	Rural
5.	School E	Rural
6.	School F	Semi-urban
7.	School G	Urban
8.	School H	Urban
9.	School I	Urban
10.	School J	Urban
11.	School K	Semi-urban
12.	School L	Urban

3.4. RESEARCH DESIGN

The researcher felt that the use of the following investigating methods would be very beneficial towards the attainment of the expected findings:

3.4.1 Structured student questionnaire

This questionnaire contained definite, concrete and pre-formulated questions for the purpose of eliciting detailed responses. The form of the questions was either closed (categorical) or open (inviting free response). The important point was that the questions were stated in advance, not constructed for instance like during the interview. Questionnaires are used in a wide range of projects, both to initiate a formal enquiry and also to supplement and check accumulated data says Young (1956).

3.4.1.1 **Reasons for using the questionnaire method**

The researcher opted for this instrument as a method of research because of the reasons that are listed below:

a) It allows the selection of a larger representative sample since it permits a wide coverage at minimum expense both in money and effort and this then leads to greater validity of the results.

b) Since it does not call for any means of identification, the questionnaire may, due to its greater impersonality, elicit candid responses.

c) It is not very mind-taxing and time-consuming and therefore makes the respondent less reluctant to participate in the research.

3.4.1.2 **The field covered by the questionnaire**

The questionnaire was meant to bring out misconceptions that the students might be having concerning the concepts of force, work and energy.

With regard to force the questionnaire aimed at finding out whether students did have some of the following naive ideas brought out by previous researchers:

a) Only one force acts on a stationary body, namely, the force of gravity, or there are no forces that are exerted on the stationary object altogether.

b) A moving object has a force within it that keeps it moving and the object will stop moving as soon as the inherent force has been dissipated.

c) The weight of an object has the same meaning as the mass of the object.

As far as the concept of work is concerned the researcher wished to establish if his sample also exhibited some of the following scientifically inappropriate ideas found by other researchers:

a) When a force is applied on an object, work is done on the object even if the object does not move.

b) No work is done on a light object like a piece of paper when it is lifted up or carried for a certain distance even if all the conditions for work to be done on an object have been satisfied.

c) There is work done on an object that is moving on its own even if there is no continuous force that is exerted on it.

d) There is no work done on an object that is falling to the ground.

e) For calculating the work done on an object, the actual distance moved by the object should be considered even if it is not in the same direction as the force that is acting on the object.

The naive beliefs under study in conjunction with energy in general and gravitational potential energy were:

i) that food and fuel are types of energy.

ii) that since food and fuel are regarded as sources of energy, energy can be created and can also be used up.

iii) that an object that is at a certain height above the ground has no gravitational potential energy if it is not about to fall to the ground or is in the process of falling to the ground.

iv) that gravitational potential energy increases as the object is falling to the ground, that is, confusing gravitational potential energy with kinetic energy.

The questionnaire was drafted and prepared for the Pilot Study in the light of the previously mentioned information.

Questions 1 to 8 were questions that were aimed at bringing out the preconceptions and misconceptions that students might have with regard to force. From question 9 to question 14, the researcher wanted to find out what misconceptions the students had as far as work that is done on an object is concerned. In questions 15 and 16, the objective was to find out whether students do not regard food and fuel as being types of energy and also how conversant the students were with the principle of Conservation of Energy. Questions 17 to 20 dealt with gravitational potential energy aiming at highlighting some of the misconceptions that the students might have concerning this concept.

3.4.1.3 **Piloting the questionnaire**

The main intention of applying the questionnaire to a Pilot Study was:

a) to provide a trial run of the questionnaire.

b) to see if the respondents could handle the questionnaire as a data-collecting instrument.

c) to identify weaknesses for early rectification and elimination.

d) to explain, if necessary, some terms referred to in the questionnaire. This step was considered essential so as to minimise the risk of receiving invalid answers due to guessing or misunderstanding on the side of the respondents.

The questionnaire for the Pilot Study consisted of multiple choice questions where the student would choose from three given responses to the question, the response he or she felt was the suitable one.

For the purpose of the Pilot Study the researcher selected 30 standard 7 students who were students of the same level as the population the study was intended for.

The Pilot Study was administered at one school in November 1994 a day before the students were to sit for the General Science Examination Paper. This was to ensure that the students had revised the section concerned before they got involved with the questionnaire. The questionnaire was administered in the morning whilst the students were fresh and active. The duration of the questionnaire was 60 minutes. For the Pilot Study 25 students were used. The first student to finish took 40 minutes to respond to all the questions required.

The results of the questionnaire were analysed and the findings are tabled here after:

a) The students had no problems with understanding the questions and accompanying responses that constituted the questionnaire. From the analysis of the results it seemed that the students had the following misconceptions:

   i) Only one force, that is, the force of gravity is acting: 1) on a book that is lying on a table, 2) on a wooden block that is hanging from a string.

   ii) A ball that is kicked, rolls on the ground and then comes to a halt, stops moving because of one of the following reasons:

      1) Since there is no more contact between the foot and the ball, the force that made it to move is not acting on it anymore.

      2) The force that the ball got from the foot of the kicker has been used up inside the ball.

iii) The weight of an object is the same as the mass of an object.

iv) Work is done on a pocket of potatoes that is carried onto the back of a truck and a bookcase that is carried horizontally for the same reason that they are both heavy, regardless of the fact that the scientific conditions for work to have been done on these two cases are different.

v) If a man is carrying a load up the stairs the work done on the load is equal to the product of the force applied on the load and the actual distance moved up the stairs.

vi) Energy can be used up sometimes.

vii) An apple that is hanging from a branch of a tree has no gravitational potential energy because it is stationary.

viii) When a stone is thrown up and then comes down, the gravitational potential energy of the stone increases as it is coming down.

b) With regard to the accompanying explanations for the response given, there seemed to be a big problem. They seemed to have a problem in expressing themselves in English and as a result the explanations they gave to support their choice of responses could not be understood by the researcher at all. Some of these explanations will be reflected in appendix B.

The Pilot Study led the researcher towards the following adjustments or conclusions:

a) Since the responses to the multiple choice questions showed indications that Black students might be having the misconceptions that the study purports to investigate, the researcher decided to keep the questions as they are for use on a large scale, that is, on the main sample of the research study.

As the only problem encountered was with giving supporting reasons, the researcher was obliged to drop this part in the multiple choice questionnaire. The investigator then opted for the structured interview using the exact questions from the questionnaire as he felt this would be an appropriate tool for extracting reasons for the student responses to the questions in order to ensure the validity of the questionnaire's responses.

b) The students' attempt to explain why they made their choices, reflected that they had a problem in expressing themselves in the language of instruction, that is, English. The researcher thus felt that it would be proper and fruitful when holding interviews with the students, in order to get the supporting reasons for their responses, to allow them to give reasons or explanations to support their responses in the vernacular, that is, Xhosa.

The complete draft of the questionnaire will be reflected in appendix A.

3.1.4.4 <u>Validity and Reliability of the questionnaire</u>

3.1.4.4.1 <u>Validity of the questionnaire</u>

In an attempt to ensure the validity of the questionnaire for the present study, the researcher took the following steps:

a) The purpose and importance of the study was clearly described in a brief and courteous cover letter so as to appeal to the respondents for their co-operation.

b) Possible alienation and boredom was avoided by careful construction of questions and by limiting the length of the questionnaire to about 40 minutes.

c) As already stated after the draft questionnaire was completed a pilot study was conducted for the purpose of identifying and eliminating possible weaknesses.

3.1.4.4.2 **Reliability of the questionnaire**

Since the present study is to be based on a quantitative analysis. The researcher applied the following measures to ensure the reliability of the questionnaire.

a) The sample was selected randomly and it was ensured that the respondents selected would constitute a representative sample. To achieve this, the sample consisted of urban, semi-urban and rural schools.

b) Careful attention was given to select as far as possible a homogeneous group of respondents. This was catered for by seeing to it that the respondents had practically the same cultural background.

3.4.2. **The interview**

Best (1984) regards the interview as often superior to other data- gathering devices. The reason as far as Best is concerned is that people are usually more willing to talk than to write. He further supports this assertion that the interview is one of the best gathering devices by highlighting the fact that in an interview the interviewer can explain the purpose of the investigation and can explain more clearly just what information he or she wants. He goes on to say that if the subject or respondent misinterprets the question the interviewer may follow it with a clarifying question.

The type of interview to be used for this research study is the structured interview.

According to Fox (1969), in the structured interview the questions are stated specifically in a fixed sequence and the interviewer asks them verbatim in the order in which they are listed.

3.4.2.1 **Reasons for using the structured interview**

a) The researcher wanted to get explanations from the students as to why they responded the way they did to the questions in the questionnaire.

b) The investigator anticipated that the questionnaire alone would not reveal the reasons why certain choices were made as experienced in the Pilot Study. He then decided to build in the interview aspect.

3.4.2.2 **Piloting the interview**

A Pilot Study was done to find out how effective the student interviews would be in bringing out the reasons for the students' inappropriate / incorrect responses to the questions in the questionnaire.

Out of the 20 questions in the questionnaire, 14 were identified for interview piloting purposes. Only those students who gave inappropriate / incorrect responses / answers in the Pilot questionnaire were used in the interview Pilot Study. The researcher had no problem in tracing these students as they had written their names in their questionnaires. The researcher sat with one student in the interviewing room at a time where he asked the student to give reasons for his or her responses (the inappropriate / incorrect ones) to the questions in the questionnaire. Each interview lasted 30 to 40 minutes, and 12 students participated in the interview process.

The table that is to follow shows some of the student interview responses.

Table 1

CONCEPT	STUDENT	INCORRECT RESPONSE	EXPLANATION GIVEN
A. FORCE	1.	There are no forces that are acting on the book that is lying on the table.	The table and the book are not moving, therefore there is no force that is acting on the book.
	2.	Only the force of gravity is acting on the book that is on the table.	The force of gravity is dragging the book down and if the table was not there the book would fall down.
	3.	A ball that is kicked and rolls on the ground stops moving eventually because the foot of the kicker is not exerting a force on the ball anymore.	The force that was causing the ball to move was the pushing force and when the pushing force was used up the ball stopped.
B. WORK	1.	There is no work done in putting a piece of paper that fell on the ground back on the table.	The piece of paper is so light there can be no work that is done on the paper.
C. ENERGY	1.	The gravitational potential energy of a stone that is dropped from a height of 4m decreases as the stone is falling to the ground.	As the stone is coming down, its speed increases and therefore its gravitational potential energy increases.

The explanations given by the students showed that the students did have preconceptions and misconceptions about the concepts of force, work and energy. For example, from the table the following patterns emerge:

a) **<u>On force</u>:** On average this is what they think.

i) There are no forces that are acting on a stationary book since it is not moving

ii) Only the force of gravity is acting on a book that is on a table as the book would fall to the ground if the table was not there. It seems that to the students the table simply acts as a support to the book, otherwise it is not exerting any force on the book.

b) **<u>On work</u>:** On average this is what they think.

There is no force that is exerted on a light object (piece of paper) in taking it from a floor onto a table and therefore no work has been done.

c) **<u>On energy</u>:** On average this is what they think.

The gravitational potential energy of a stone that is dropped to the ground from a certain height increases because the speed of the stone increases as the stone is approaching the ground. The students seem to be confusing gravitational potential energy with kinetic energy.

These findings made the researcher regard the interview process as the most important tool for the research study.

3.4.3 <u>Lesson observation</u>

To get an idea of where some of the detected misconceptions came from the researcher felt that it would be a good idea to observe teachers as they were teaching these concepts.

A Pilot Study was conducted at one of the schools where a standard 7 General Science teacher was observed while teaching the concept of **force.**

The following observation convinced the researcher that including lesson observation to the study on a larger scale could be beneficial to the final outcome of the research.

The teacher seemed to be confusing the concepts of **force** and **power.** He referred to the force of gravity as the earth's pulling **power** on an object, when he meant to say the earth's pulling **force**.

3.4.4 <u>Analysis of textbooks</u>

To find out even more about the source of student misconceptions, the researcher decided to look at how the prescribed textbooks present the concepts to the students and teachers.

The prescribed textbook for the standard 7 students, written by Scholtz et al (1993), which was used at the school where lesson observation was piloted, was analysed for how it treated the concepts of force, work and energy.

In his investigation the researcher came across a statement in the said textbook that he felt might result in a misconception on the part of the students. The statement is quoted below:

"Work is done on an object only when a force acts over a distance, causing movement in the direction in which the force acts. When the displacement of the object due to the action of the force, is not in the same direction as that of the force, no work is done".

The part of the statement that says that the object should move in the direction in which the force is applied might mislead the students. Room should be made for preparing students to be equipped for more information which will be coming in at a later stage (standard 9). In standard 9 the students will learn that an object can act at an angle to an object, and if the students are not made aware of this fact in standard 7, this might lead to a misconception.

This finding prompted the researcher to analyse other textbooks that are prescribed for the standard 7 level for comparison.

3.5. RESEARCH METHODOLOGY

3.5.1 Sources of data

Sources of data were standard 7 students and their teachers at selected schools, and textbooks recommended for the level being studied.

3.5.2 Methods of gathering data

3.5.2.1 The questionnaire

The researcher visited the selected schools personally and carried out the administration of the questionnaires himself to ensure 100% return of the questionnaires and also to clarify what ever needed explanation so that the responses of the students could be as genuine as possible. A total of 315 questionnaires were to be distributed to the students in the selected schools. This was carried out in March and April 1995 just immediately after the section concerned had been completed in each of the selected schools.

The results were then compiled and analysed as indicated in Chapter 4.

3.5.2.2 The interview

The significant results in the analysis of the questionnaire prompted the researcher to opt for an interview in order to obtain reasons from the students as to why they responded the way they did.

A random sample of students was selected for the interview from 3 of the schools. These schools were part of the research sample. From each school 15 students were to be interviewed, making a total of 45 students.

It is 14 questions from the questionnaire that formed the basic questions of the interview. These were questions in which the students' responses to the questions in the Pilot Study appeared to indicate that students might have misconceptions with regard to the concepts concerned. The questions referred to were 1, 2, 3, 4, 5, 6, 8, 10, 11, 14, 16, 17, 19 and 20.

Three interview sessions were held in the selected schools. In each interview session the researcher went through each of the selected questions of the questionnaire with each student individually. The student was required to give a reason to support his or her selection of the answer to the question. The explanations could be given in the students' mother tongue. The researcher translated the explanations to English for the purpose of reporting without changing the meaning and context of the reason. Explanations that were given in English would be reported as they were as long as they were meaningful.

The researcher made sure that the sessions were conducted in a free and friendly atmosphere . To establish this, the researcher made the students at ease by explaining to them:

a) that this was not a test or examination but a research study whose results could be of great benefit not only to the students interviewed but to all Black students in general.

b) that what transpired in the interview sessions would not be communicated with the students' subject teachers.

Students' explanations were then analysed as shown in Section B of Chapter 4 that deals with findings from the interviews with the students.

3.5.2.3 **Lesson observations**

The researcher felt that it would be beneficial to check how the teachers taught the concepts under investigation to see whether they did not contribute to the naive ideas or misconceptions that the students might have. Lesson observations were arranged with teachers from the schools that constituted the research study sample. The investigator visited the teachers while they were teaching or introducing the concepts of force, work and energy.

These observations are reported and discussed in detail in Section C of Chapter 4.

3.5.2.4 **Analysis of textbooks**

Textbooks recommended for use by students at the level that was being investigated, that is, standard 7, were analysed by the researcher to try and find out how far the textbooks contributed towards worsening teaching and learning problems, since the textbook appears to be regarded as the main source of information by the teachers and students. The findings in this regard are published in Section D of Chapter 4.

CHAPTER 4

ANALYSIS OF RESULTS

4.1 INTRODUCTION

4.2 ANALYSIS OF STUDENT QUESTIONNAIRES

4.3 FINDINGS FROM INTERVIEWS WITH STUDENTS

4.4 FINDINGS FROM LESSON OBSERVATIONS

4.4.1 OBSERVATION OF THE TEACHING OF THE CONCEPT OF FORCE

4.4.2 OBSERVATION OF THE TEACHING OF THE CONCEPTS OF WORK AND ENERGY

4.4.3 CONCLUSION

4.5 FINDINGS FROM ANALYSIS OF THE PRESCRIBED TEXTBOOKS

4.5.1 HANDLING OF THE CONCEPT OF "FORCE" IN THE TEXTBOOKS

4.5.2 ANALYSIS OF THE HANDLING OF THE CONCEPT OF "WORK" IN THE TEXTBOOKS

4.5.3 CONCLUSIONS

CHAPTER 4

ANALYSIS OF RESULTS

4.1 INTRODUCTION

An analysis and discussion of the results of the study that have been obtained through employing the methodology that has been fully explained in Chapter 3, is dealt with in detail in this chapter.

The present chapter is divided into four sections as indicated below:

i) Section A: **Analysis of student questionnaires**

Section A deals with the preliminary analysis of the responses of the students to the questionnaires that they were required to complete. Tables reflecting the statements and students responses per question are furnished with the appropriate/correct answers/responses marked with a star (*).

ii) Section B: **Findings from interviews with the students**

This section looks at the reasons given by the students, who have been selected from the main sample to support their responses to some of the statements in the questionnaire. Because of in-built errors a statistical analysis is not going to be reflected in this section.

iii) Section C: **Findings from lesson observations**

Findings from observing lessons taught by the standard 7 General Science teachers on the concepts concerned are explicitly discussed in this section.

iv) Section D: **Findings from analysis of the prescribed textbooks**

The present study was also concerned with the analysis of the textbooks that are used in standard seven. Subsequent findings are highlighted in this section.

4.2 SECTION A

ANALYSIS OF THE STUDENT QUESTIONNAIRE

This is a preliminary analysis of the responses of the students to the questions they were required to answer in the multiple choice questionnaire. The responses are analysed per question. The questions are rewritten with the analysis next to each statement followed by graphical representation and a short description. There is an inconsistency in the total number of frequencies due to the fact that the students were allowed to choose as many answers as they felt were scientifically suitable to the question, that is, a student could choose more than one statement in a question.

Question 1

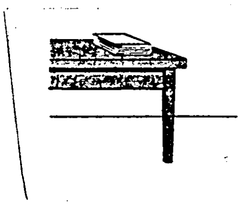


Figure 4.1

The figure above shows a book lying on the table.

Table 4.1. Responses to Question 1 in the questionnaire.

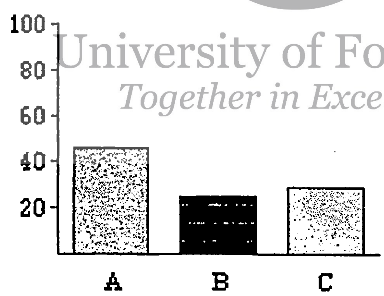
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
*A	There are two forces acting on the book, upward and downward.	140	46,51
B	There are no forces acting on the book.	74	24,51
C	Only the force of gravity is acting on the book.	87	28,98
	TOTAL	301	100,0

A is the appropriate scientific view.

Graph 4.1.

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

According to the above table 46,51% of the students have the appropriate conception that two forces are acting on the book, but we cannot discard the fact that a significant number of students, i.e.: 28,90%, are of the opinion that only one force, i.e.: the force of gravity is acting on the book. The students seem to find it difficult to accept that a passive object like a table does indeed exert a force. They only recognise the downward force of gravity.

<u>Question 2</u>

In the figure below a wooden block is shown hanging from a string.

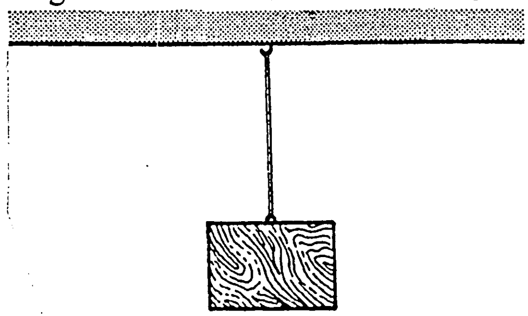


Figure 4.2

Table 4.2 Responses to question 2 in the questionnaire.

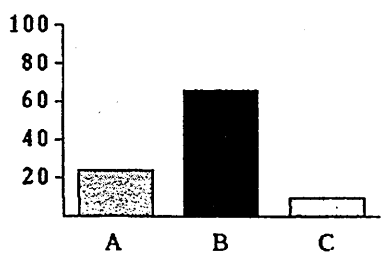
	STATEMENTS	RESPONSES OF STUDENTS	
		FREQUENCY	PERCENTAGE
A	There is only one force acting on the block i.e.: force of gravity	71	24,40
*B	There are two forces acting on the block	192	65,98
C	There are no forces acting on the block	28	9,62
	TOTAL	291	100,00

B is the acceptable scientific view.

Graph 4.2

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

Most of the students, 65,98%, are of the opinion that there are two forces that are acting on the block, i.e.: upward and downward, which is a scientifically appropriate statement compared to question 1 where 46,51% responded that there are two forces involved. It is 24,4% that is of the opinion that the force of gravity is the only force. Only an insignificant number of respondents had the idea that there are no forces that are acting on the block, i.e.: 9,62%.

Question 3

A ball is kicked, rolls on the flat ground and then stops moving eventually. The reason why it stops moving is because:

Table 4.3 Responses to question 3 in the questionnaire:

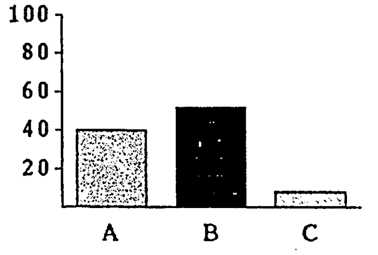
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
A	The foot is not exerting a force on the ball anymore.	116	39,73
*B	Of the frictional force acting in the opposite direction to the motion of the ball	153	52,40
C	Of neither A nor B	23	7,87
	TOTAL	292	100,00

The appropriate choice in this case is B.

Graph 4.3

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

As indicated in table 4.3, 52,40% could select the suitable answer to the question, though 39,73%, which is a significant number, are of the opinion that there should be continuous contact between the foot and the ball in order to keep the ball moving. The 39,73% of the respondents seem to be of the opinion that there should be continuous contact between the foot and the ball in order to keep it moving which is an interesting result.

Question 4

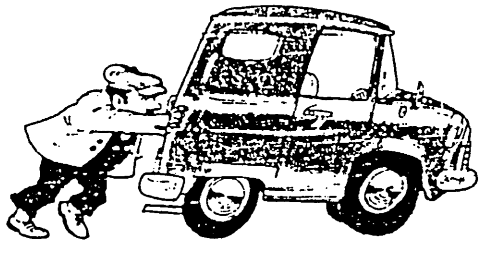


Figure 4.4

The man is pushing the car and the car does not move.

With regard to the above diagram which of the following statement is true?

Table 4.4 Responses to question 4 in the questionnaire

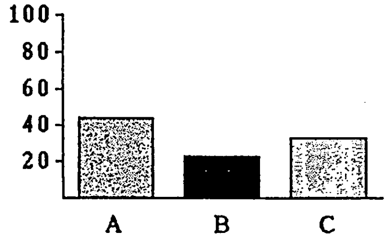
	STATEMENTS	RESPONSES OF STUDENTS	
		FREQUENCY	PERCENTAGE
A	Only the pushing force from the man is acting on the car.	132	43,85
*B	Four forces are acting on the car, i.e.: frictional force, force of gravity, pushing force from the man and upward force exerted by the ground on the car	96	22,93
C	No forces are acting on the car.	100	33,22
	TOTAL	301	100,00

B is the suitable choice.

Graph 4.4

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

Table 4.4 shows that 43,85% viewed that only the pushing force from the man is exerted on the car. Only 22,93% could choose the appropriate response. The fact that 33,22% felt that there are no forces that are acting on the car shows that the majority of the students (77,07%, that is, 43,85% + 33,22%) had no appropriate conception of what is involved in this question. They seem to reject the fact that more than one force does act on an object at the same time.

Question 5

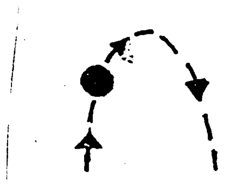


Figure 4.5

As the ball is going up, which of the following is true about the force that is acting on the ball?

A :  B :  C : ○ no force

Table 4.5 Responses to question 5 in the questionnaire.

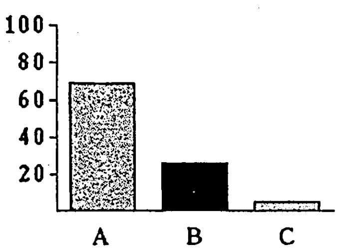
DIAGRAMS			RESPONSES OF STUDENTS	
			FREQUENCY	PERCENTAGE
A			207	69,23
*B			73	26,09
C	no force		14	4,68
		TOTAL	299	100,00

B is the appropriate response.

Graph 4.5

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The results show that 69,23% of the respondents have the idea that there is a force that is exerted on the ball which makes it move in the upward direction. Only 26,09% have said that the force that is acting on the ball is in the downward direction, (force of gravity), which is the accepted view.

Question 6

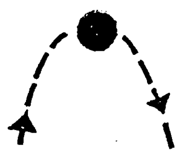


Figure 4.6

As the ball is just at the top of its flight, the force acting on the ball is shown in:

A :    B :    C : ○ no force

Table 4.6 Responses to question 6 in the questionnaire

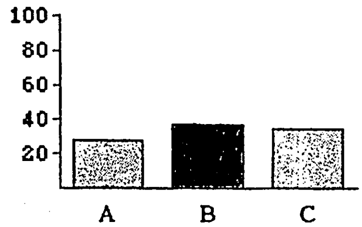
		RESPONSES OF STUDENTS	
	DIAGRAMS	FREQUENCY	PERCENTAGE
A		82	28,18
*B		108	37,11
C	no force	101	34,71
	TOTAL	291	100,00

B is the appropriate response.

Graph 4.6

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

In this case 37,11% responded that there is a downward force that is acting on the ball, that is, the force of gravity, which is an appropriate view. Table 4.6 reflects that 34,71% is of the feeling that there is no force that is acting on the ball at this position. There is a large number of students who lack the appropriate scientific understanding as far as the above question is concerned, because when you add the responses A and C you get a total of 62,89%.

<u>Question 7</u>

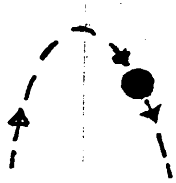


Figure 4.7

If the ball is on its way down, the total force acting on the ball is shown in:

A :  B :  C :  no force

Table 4.7 Responses to question 7 in the questionnaire.

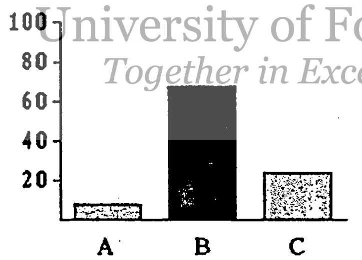
	DIAGRAM		RESPONSES OF STUDENTS	
			FREQUENCY	PERCENTAGE
A			22	7,64
*B			196	68,06
C	 no force		70	24,30
		TOTAL	288	100,00

The suitable response is B.

Graph 4.7

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The majority of the respondents, 68,06%, indicated that there is only a downward force that is acting on the ball. Only 24,11% felt that there is no force that is acting on the ball.

Question 8

The mass of a girl is indicated as 36 kg. on a bathroom scale. Her weight is:

Table 4.8 Responses to question 8 in the questionnaire:

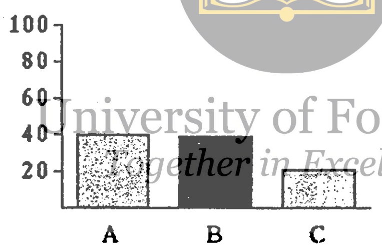
		RESPONSES OF STUDENTS	
	ANSWERS	FREQUENCY	PERCENTAGE
A	36 kg	120	40,00
*B	360 N	116	38,67
C	36 N	64	21,33
	TOTAL	300	100,00

B is the suitable choice.

Graph 4.8

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

In the above analysis it is indicated that 40% of the respondents regarded the weight of the girl to be 36 kg. At least 38,67% had the appropriate conception that weight is mass x 10 ms^{-2}. That 71,33% could not pick up the suitable scientific view implies that there is a significant number of students who do not have a scientific understanding of the concept of weight.

Question 9

A man pushes a wall with a force of 800N, but the wall does not move.

The work done in a scientific sense, is:

Table 4.9 Responses to question 9 in the questionnaire

RESPONSES OF STUDENTS

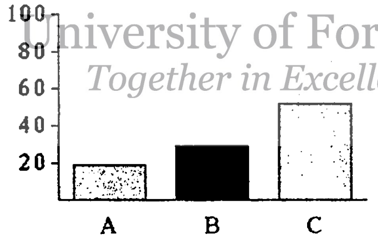
	ANSWER		FREQUENCY	PERCENTAGE
A	800 N		55	18,97
B	800 J		84	28,98
*C	0 J		151	52,05
		TOTAL	290	100,00

C is the appropriate response.

Graph 4.9

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

According to the above information, 52,05% knew that the work done is 0 J, that is, there is no work done since the wall did not move. When A and B are added, 47,95% seem not to understand that work is done on an object only when the object has moved a certain distance no matter how huge the applied force is.

Question 10

In which of the following cases is there no work done on the object in the scientific sense?

Table 4.10 Responses to question 10 in the questionnaire

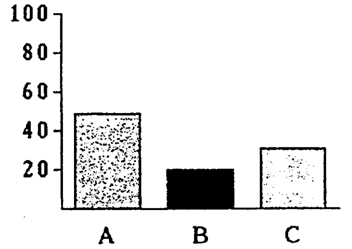
	STATEMENTS	RESPONSES OF STUDENTS FREQUENCY	PERCENTAGE
A	A piece of paper that fell on the ground is put back on the table.	141	48,79
B	A pocket of potatoes is lifted from the ground onto the back of a truck.	57	19,72
*C	A student who has his book bag (ubhaka) on his back walks a horizontal distance of 20 m.	91	31,49
	TOTAL	289	100,00

C is the appropriate conception.

Graph 4.10

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

As indicated in table 4.10, 48,79% responded that there is no work done on the piece of paper when it is taken from the ground onto the table. Only 31,40% had the appropriate scientific view that there is no work done on the object that is carried through a horizontal distance no matter how heavy it is. The table also reflects that 19,72% felt that no work is done on a bag of potatoes when it is lifted onto the back of a truck. The sum of A and B which is 68,51% is quite a significant number not to understand that no work is done on an object when it is carried along a horizontal distance.

Question 11

A ball is moving on a flat surface with constant speed past point A and B. As indicated in the diagram below:

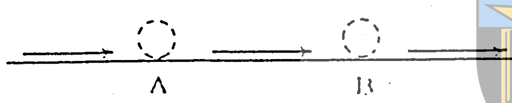


Figure 4.11

(As the ball is moving past points A and B).

Is work done on the ball between A and B?

Table 4.11 Responses to question 11 in the questionnaire

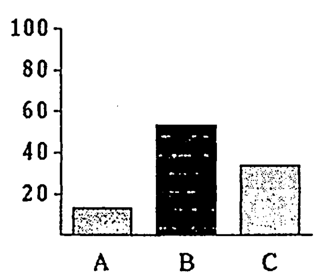
	STATEMENTS	RESPONSES OF STUDENTS FREQUENCY	PERCENTAGE
*A	In the time between A and B there was no work done on the ball because there was no horizontal force acting on the ball	38	12,93
B	Work was done on the ball because the ball has moved between A and B.	157	53,40
C	Not enough information is given in order to decide whether work is done on the ball or not.	99	33,67
	TOTAL	294	100,00

The appropriate conception is A.

Graph 4.11

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The results reveal that a reasonable number of respondents, that is, 53,40% had the view that work was done on the ball in the time between A and B. They seem to disregard the fact that for work to be done on an object there should be a force that acts on the ball continuously over a distance AB. As table 4.11 shows, 33,67% said that there is not enough information to make any conclusion. Only 12,93% could get the required response. The fact that 87,07% could not choose the appropriate response reflects that there are many students who lack a proper understanding of the scientific meaning of the concept of work.

Question 12

A ball is allowed to fall on its own from a height of 4m above the ground. Is there any work done on the ball as the ball falls?

Table 4.12 Responses to question 12 of the questionnaire

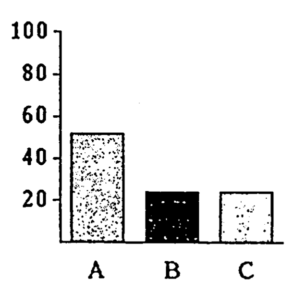
	STATEMENTS		RESPONSES OF STUDENTS FREQUENCY	PERCENTAGE
*A	Yes		144	51,42
B	No		68	24,29
C	Not sure		68	24,29
		TOTAL	280	100,00

The scientifically accepted choice is A.

Graph 4.12

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The 51,41% who made the appropriate choice that work is done when an object falls on its own supported the idea the force of gravity is acting on the object and it has moved a certain distance. Some of the respondents, that is, 24,29%, were of the opinion that there was no work done in this case. The rest of the respondents, that is, 24,29% seem not to be clear of what was going on.

Question 13

Has work been done in unscrewing (opening) a lid of a bottle?

Table 4.13 Responses to question 13 in the questionnaire

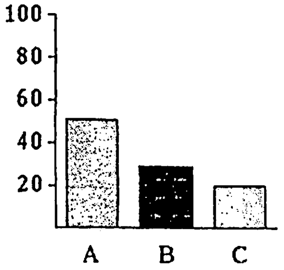
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
*A	Yes	148	50,68
B	No	84	28,77
C	Not sure	60	20,55
	TOTAL	292	100,00

A is the scientifically accepted response.

Graph 4.13

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The above results show that 50,68% knew that work is done when successfully unscrewing a lid of a bottle. since a force was applied and the lid moved a certain distance. The fact that

28,77% said that no work has been done and 20,55% were not sure implies that 49,32% did not have the appropriate scientific knowledge of work done as far as this particular case is involved.

Question 14

In the figure below, a boy is shown carrying a load up the stairs.

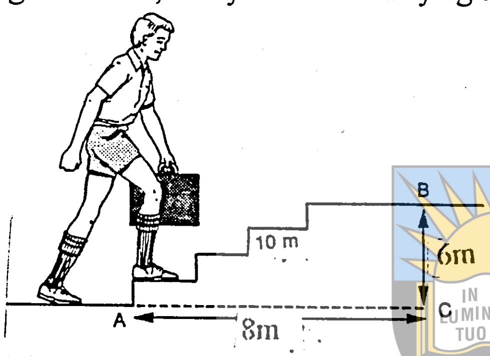


Figure 4.14

A boy carrying a load up the stairs

The boy exerts an upward force of 100N in carrying the load up the steps from point A to B.

The work done is:

Table 4.14 Responses to question 14 in the questionnaire

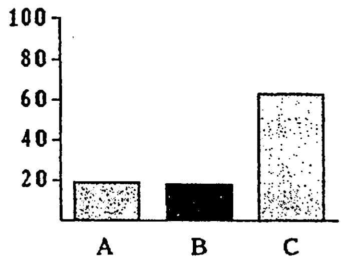
	STATEMENTS		RESPONSES OF STUDENTS	
			FREQUENCY	PERCENTAGE
*A	100 N x 6m		59	19,34
B	100N x 8m		56	18,36
C	100N x 10m		190	62,30
		TOTAL	305	100,00

A is the appropriate response.

Graph 4.14

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The above analysis reflects that 62,30%, that is, the majority of the respondents, have the idea that the work done in the said case is equal to the product of the force applied and the actual distance moved. Only 19,24% could get the appropriate answer to the question, whilst 18,36% had the misconception that the work done is equal to the product of the force exerted and the horizontal distance. From the fact that 80,66% chose B and C, which are inappropriate responses, one can deduce that the scientific understanding of the concept of work by the students is a big problem.

<u>**Question 15**</u>

Which of the following statements is scientifically true about fuel (petrol) and food?

Table 4.15 Responses to question 15 in the questionnaire

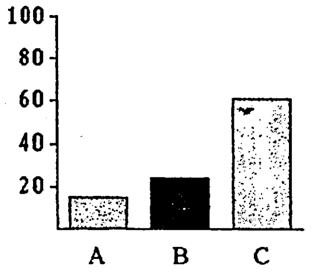
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
A	Fuel is a type of energy	46	14,60
B	Food is a type of energy	77	24,44
*C	Fuel and food are sources of energy	192	60,96
	TOTAL	315	100,00

The required choice is C.

Graph 4.15

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

Table 4.15 reveals that 60,96% of the respondents in this group had the appropriate scientific view that fuel and food are sources of energy. It is also reflected that 24,44% regarded food as a type of energy compared to 14,60% which took fuel as a kind of energy.

<u>Question 16</u>

Scientifically speaking, which of the following statements concerning energy is correct?

Table 4.16 Responses to question 16 in the questionnaire

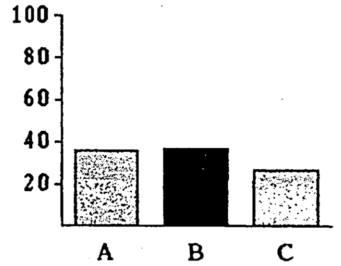
	STATEMENTS	RESPONSES OF STUDENTS FREQUENCY	PERCENTAGE
A	Energy can be used up sometimes	116	35,58
*B	Energy can never be destroyed.	122	37,42
*C	Energy can never be created.	88	27,00
	TOTAL	326	100,00

B and C are the appropriate choices.

Graph 4.16

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

As indicated above 35,58% had the view that energy can be used up sometimes. The results also show that 37,42% felt that energy can never be destroyed which is the appropriate scientific view compared to 27% which said that energy can never be created which is also an accepted scientific idea.

Question 17

Does an apple that is lying on the table with a height of 1m above the ground have gravitational potential energy?

Table 4.17 Responses to question 17 in the questionnaire

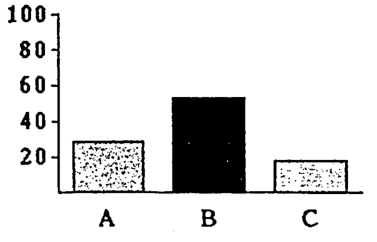
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
A	No	85	29,11
*B	Yes	154	52,74
C	Not sure	53	18,15
	TOTAL	292	100,00

B is the appropriate view.

Graph 4.17

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

From the above analysis it is noted that 52,74% responded that the apple has gravitational potential energy at the given position whilst 29,11% opposed that. There is 18,15% that need more clarity in this regard. In total, 47,20% of the students surveyed seem to lack the expected scientific understanding of the concept of gravitational energy.

Question 18.

Does an apple that is hanging from a branch of a tree 2m above the ground have gravitational potential energy?

Table 4.18 Responses to question 18 in the questionnaire

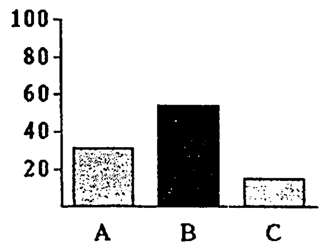
		RESPONSES OF STUDENTS	
	STATEMENTS	FREQUENCY	PERCENTAGE
A	No	87%	30,53
*B	Yes	155	54,39
C	Not sure	43	15,08
	TOTAL	285	100,00

B is the suitable choice.

Graph 4.18

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

In this particular case 54,39% said that the apple on the branch has gravitational potential energy. Those who felt that the apple on the branch of the tree has no potential gravitational energy constituted 30,53%.

Question 19.

When a stone is dropped from a height of 4m to fall to the ground:-

Table 4.19 Responses to question 19 in the questionnaire

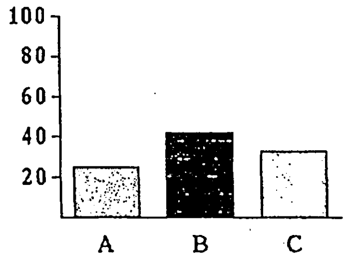
	STATEMENTS	RESPONSES OF THE STUDENTS	
		FREQUENCY	PERCENTAGE
*A	The gravitational potential energy of the stone decreases as it is falling to the ground.	73	24,66
B	The gravitational potential energy increases as it is falling to the ground.	124	41,89
C	The gravitational potential energy remains the same as it is falling to the ground.	99	33,45
	TOTAL	296	100,00

A is the appropriate response.

Graph 4.19

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

According to what is indicated in the above results, 41,89% of the respondents are of the opinion that the gravitational potential energy of a body increases as it is falling to the ground. Only 24,66% had the appropriate response, whilst 33,45% felt that the gravitational potential energy remains the same as the stone is falling to the ground. A large percentage of the respondents (75,11%) could not pick up the appropriate scientific view and this is a matter of concern.

Question 20

As an object is moved further away from the centre of the earth:

Table 4.20 Responses to question 20 in the questionnaire

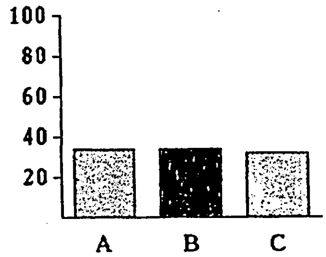
	STATEMENTS	RESPONSES OF STUDENTS FREQUENCY	PERCENTAGE
A	the gravitational potential energy of the object decreases.	107	34,08
*B	the weight of the object decreases.	106	33,76
C	the mass of the object decreases.	101	32,16
	TOTAL	314	100,00

The expected choice is B.

Graph 4.20

GRAPHICAL REPRESENTATION:

PERCENTAGE



STATEMENTS

The results displayed above reveal that only 33,76% seemed to know that it is the weight of an object that decreases as the object is moved away from the centre of the earth. Some of the respondents (34,08%) believed that the gravitational potential energy of the object decreases as it is moved away from the centre of the earth. There were respondents, that is, 32,16%, who seemed to be of the opinion that it is the mass of the object that decreases as the object is moved away from the centre of the earth. A total of 66,24 could not choose the appropriate response.

4.3 SECTION B

FINDINGS FROM INTERVIEWS WITH STUDENTS

The researcher was curious to know the reasons behind the inappropriate responses. The researcher was convinced that the only investigating tool that could fulfill this curiosity was the interview. Asking the students to write down the reasons for their choices in the questionnaire had proved to be a futile exercise as reflected in the Pilot Study findings because the students gave unclear expressions. Some of the students just left the space allowed for reasons blank. Conducting interviews with the students to get reasons for the choices made appeared to be the best option.

The students that were interviewed were taken from the same group that was used for testing as indicated in the research methodology.

For the interview analysis the researcher decided to group the results into two categories, A and B.

Category A:

Where the researcher found 33% or more of the students giving a certain incorrect response he treated that as being significant and analysed that particular response further using the interview as an instrument to find out the underlying causes.

Category B:

Where the researcher found that the majority (more than 50%) of the responses were incorrect, that convinced him that there was a problem there. The researcher looked at the incorrect responses and isolated those that were 24% or more and analysed them.

When discussing the interview findings the researcher will start with the analysis of the Category A responses and thereafter Category B.

When reporting, the researcher will start with indicating which question he is referring to, and following thereafter, the discussion of findings of the interviews. The symbol S is used to represent a student, S_1 refers to the first student, S_2 to the second student, and so on.

QUESTIONS	PERCENTAGE OF RESPONSES
3A	39,73
4A	43,85
4C	33,22
5A	69,23
6C	34,71
8A	40,00
10A	48,79
11B	53,40
11C	33,67
14C	62,30
16A	35,58
19B	41,89
19C	33,45
20A	34,08

Question 3

Discussion

The appropriate/correct statement in this question is 3B which states that a ball that is kicked, rolls on the ground and stops moving eventually, stops because of the frictional force that is acting on it in the opposite direction.

The analysis of results has revealed that 39,73% of the students have the incorrect view that a ball that is kicked and rolls on the ground stops because the foot is not exerting a force on the ball anymore which is statement 3A in the questionnaire. Since this statement is incorrect and more than 33% selected it, students were interviewed to find out why they selected this statement.

To qualify their choice of statement 3A the students gave the following reasons:

S_1 There is no force that is exerted on the book and emphasizing in Xhosa he said "Ihleli nje" meaning that it is just resting.

S_2 The table has got no force and therefore it is wrong to say there is a force that is exerted on the book by the table.

S_3 "Akukhonto icinezela incwadi, ke iforce ayikho". This means that there is nothing that is exerting a force on the book and therefore there is no force.

S_4 There is no force because the book is not moving.

S_5 The table and the book are not moving.

Summary View

The statements from the students are evidence of the fact that the students seemed to have the idea that the force from the kicking foot was transferred to the ball and as the ball was moving the force inside the ball gradually diminished until it was used up and as a result the ball stopped. These students might be intuitively believing that an internal force that has been implanted in the object is responsible for the motion of the object, and that this internal force ultimately dissipates, causing the object to gradually come to a halt, and that is incorrect.

Question 4

Discussion

The appropriate response is 4B which states that when a man is pushing a car and the car does not move, four forces are acting on the car, frictional force, force of gravity, pushing force from the man and upward force exerted by the ground.

It could be observed from the analysis that there were students who supported the following two views, that is, responses 4A and 4C.

Discussion of response 4A

It was 43,85% of the students that supported the view that if a car is pushed but remained stationary, there is only one force that is acting on the object, the pushing force, that is, response 4A.

When the students were interviewed with regard to question 4, those students who supported the first view (4A) gave the following reasons:-

S_1 We are only told that the man is pushing the car. We are not told about any other force.

S_2 Before the man came to push the car there were no forces acting on the car. So therefore only the pushing force from the man is exerted on the car.

S_3 The car was just standing there on its own. It is the man who came with his energy and used force to push the car.

S_4 A man cannot push a big car for himself.

S_5 There is only one method of pushing a car, that is, when it is pushed by someone.

S_6 There is only one force because if there were more than one forces that are acting on the car, the car would move. The force from one man is not enough to make the car move.

Summary view for 4A

All the above cases seem to imply that since the man is pushing the car, the pushing force from the man is the only force that is acting on the car. The students seem to be considering only visible forces to be acting on objects like the man that they can see pushing the car.

Discussion of response 4C

Response 4C, which carried the idea that no forces are acting on a car if a car is pushed without moving it, was selected by 33,22% of the respondents.

The students who felt that statement 4C was the suitable choice stated the reasons given below to support their choice:

S_1: The force is not sufficient enough to make the car move, therefore there is no force that is acting on the car.

S_2: He is just wasting his energy. The car is heavy and therefore will not move. There would be a force that is acting on the car if it was moving.

S_3 The man has no force that can make the car move.

The above statements clearly indicate that the students appear to be of the opinion that forces are acting on an object if the object is moving, that is, they only seem to associate force with motion.

Summary View for 4C

The students seemed to be having the false impression that a force is regarded to be acting on an object only if the object is moving.

Question 5

Discussion

The correct response is 5B which indicates that the force that is acting on a ball that is going up is a downward force (force of gravity).

The majority of the students (69,23%) chose the incorrect statement 5A which says that when the ball is moving up only the upward force is acting on the ball. The researcher then decided to interview the students.

The students gave the following explanations to drive their point home:

S_1: The person has given it (the ball) the force that makes it move.

S_2: The force must be in the upward direction because the ball is moving up.

S_3: Since the ball is moving up, only the upward force is acting on the ball and if the force of gravity was acting on the ball, the ball would move downwards.

S_4 The ball is still going up, it is not coming down yet and therefore the force that it is having is still going up.

Quite a number of students repeatedly gave the statement that the ball is moving up because of the force that it got from the thrower's hand.

Summary View

It is apparent from the statements given that the students have the incorrect view that a moving object has an inherent force which is in the direction of motion, hence they conclude that the ball could not move up whilst the force is acting downwards. It is in fact possible for motion to be in a direction opposite to the force identified to be the force exerted. This thinking trend might be a reason as to why it seems difficult for students to identify friction as a force and to work with it as friction force which is in the opposite direction to motion.

Question 6

Discussion

The appropriate choice in this question is diagram 6B which shows that a downward force is the force that is exerted on the ball when it is just at the top of its flight.

Some of the students selected statement 6C, which asserts that there are no forces that are acting on an object when it is coming down, that is, to the ground. As it is 34% of the students supported this view as reflected in the questionnaire analysis, and the researcher wanted to know why the students supported this view, hence he opted for the interview.

Three students who were interviewed gave the following reasons to support their choice of statement 6C.

S_1 When it is coming down, there is no force.

S_2 The force that was making the ball to move up has dissipated and that is why it is now coming down.

S_3 There is no force, if there was a force the ball would be kept up there.

Summary view for 6C

The general opinion of the above students was that there is no force that is acting on an object that is falling towards the ground.

Discussions of response 6A

Discussion

Though it is 28,18% of the students that supported response 6A which indicates that an upward force is acting on a ball that is at the top of its flight, the researcher decided to discuss this incorrect response 6A with incorrect response 6C which falls under Category A. Response 6A belongs to Category B. This has been done to keep question 6 together.

The common explanation given by the students when they were interviewed to get reasons for their support of response 6A was as said by S_1.

S_1 "The ball is still up there and therefore the upward force is still acting on it (the ball)".

Summary View for 6A

The students seemed to think that as long as an object is up in the air and not yet coming down, there is an upward force that is acting on the object.

Question 8

Discussion

The appropriate/correct statement in this question is 8B which states that the weight of a girl whose mass is indicated as 36 kg on a bathroom scale, is 360N. In table 8.1 it is indicated that 40% of the respondents regarded that weight of the girl as being 36 kg which was an inappropriate choice. I then proceeded through the interview to find out why they thought so. The students who said that the weight of the girl is 36 kg, that is, those who chose incorrect statement 8A as the appropriate response, gave the following explanations as facts supporting their choice:

S_1: The mass is given as 36 kg which is the same thing as what is asked.

S_2: A person's weight is not measured in newtons but in kilograms.

S_3: The kilograms that are shown on the bathroom scale cannot be changed to newtons.

S_4: Only small objects are measured in newtons. A person's weight is measured in kilograms not in newtons.

S_5: The weight would be in newtons if the spring balance was used.

S_6: Because she has 36 kg on the bathroom scale, her weight will be 36 kg.

Having looked analytically at the above statements, the researcher observed that the students seem to be misled by the fact that massmeters which are calibrated in kilograms purport to determine one's weight in everyday life. Nowhere on the massmeters is there any explanation on how the mass is converted to the weight that is measured. The students are likely to end up confusing weight with mass as it is evident in the above arguments. S_4 and S_5 did understand that when using a spring balance the weight of the objects are measured in newtons, but seemed to think that the weight that is in newtons as indicated on the spring balances only refers to weight of small bodies, that is, bodies or objects whose weight can be determined using spring balances. They seemed to think that since the bathroom scales and other massmeters, that are said to be instruments to determine weight, are calibrated in kilograms the weight that is measured using those instruments is in kilograms.

Summary View

A general trend of thinking in this regard which the researcher has noticed is that weight of human beings is expressed in kilograms. The students might be misled by the fact that people in everyday life use massmeters to determine their weight and their weight is regarded as being the value that is reflected on the massmeter in the units of the massmeter (kilograms).

Question 10

Discussion

Statement 10C is the appropriate choice for this question. Statement 10C asserts that a student who has his book bag (ubhaka) on his back and walks a horizontal distance of 20m is said to be doing no work on the book bag.

That 48,79% of the students selected the inappropriate response 10A prompted the researcher to investigate further why they made this choice. The instrument used for this purpose was the interview.

Response 10A which states that there is no work done on a piece of paper which fell on the ground when it is put back on the table, was supported by the students in the interview with the following reasons:

S_1: The piece of paper has no force, therefore there is no work done on the piece of paper.

S_2: It is because the paper has no weight, that is why there is no work done.

S_3: The piece of paper is light so there can be no work that is done on the paper.

S_4: The piece of paper has no work done.

S_5: There is no force used in moving the paper the distance it moved to the top of the table, therefore no work has been done on the paper.

Summary View

The common idea that seemed to be prevailing in the above students was that since the paper is light no force is exerted on the paper in putting it back onto the table and therefore there is no work that is done on the paper. Generally the students seemed to think that there is no work that is done in moving a light object like a piece of paper from one place to another.

Question 11

Discussion

The appropriate view in this case is contained in statement 11A which says that there was no work done on a ball that was moving on a flat surface past points A and B because there was no horizontal force that was acting on the ball. A large number of students (53,40%) opted for the incorrect response 11B which stated that work was done on the ball because the ball has moved past A and B. The researcher was worried about this and opted for an interview.

The following statements are the students' attempts to explain why they supported response 11B which stated that work was done when a moving ball rolled past points A and B. These statements were voiced out during the interview process.

S_1: Since the ball was moving when it went past A and B, work was done.

S_2: A force was used in rolling the ball and it moved past A and B, therefore work was done on the ball.

S_3: If there was no work done on the ball, the ball would not be able to move past A and B.

S_4: There is a distance between A and B, therefore work has been done.

The 4 statements above seem to emphasize the fact that the ball was moving when it went past A and B.

Summary View

The students seemed to be concluding that since there is a force inside the ball which is causing its motion and the ball covered the distance between A and B, work must therefore have been done on the ball. The researcher was then made to believe that the students have the misconception that a moving object has an inherent force within it.

Question 14

Discussion

The suitable choice in this question is statement 14A which reflects that the work done by a boy on a load that he carries up the stairs to a point that is 6m high from the ground with a force of 100N exerted on the load, is 100N x 6m.

Many of the students (62,30%) were of the incorrect opinion that work done by a boy in carrying a load a distance of 10m up the stairs is equal to the product of the 10m distance covered and 100N force exerted by the boy on the load, statement 14C. Table A bears testimony to this. Reasons given by the interviewed students to justify their selection of the appropriate response were as follows:

S_1: You climb up the stairs a distance of 10m. That is the distance that must be used for the calculation.

S_2: The boy moved up the stairs that measured 10m. 10m therefore is the distance covered. Work done therefore is equal to 100N x 10m.

S_3: "This boy goes up the stairs which are 10m long, therefore work done is equal to 100N x 6m".

S_4: The boy is moving up and the distance moved is 10m. We have to use 10m for calculating the work done.

These students seemed to be of the idea that work done on an object is equal to the product of the actual distance, that is, the distance from the foot (beginning) of the stairs to the top (end) of the stairs, that is moved and the force that is exerted on the object.

Summary View

The above students seemed to miss out on the fact that the distance/displacement considered for work calculations has to be in the same direction as the force that is exerted.

Question 16

Discussion

As far as this question is concerned, the appropriate/correct responses are statements 16B and 16C which state that energy can neither be destroyed nor created. It was the 35,58% of the students that supported the view that energy can be used up sometimes that made the researcher curious to investigate further what reasons the students would give to support their choice. The investigating tool that the researcher deemed appropriate for this job was the interview.

Interviewed students who opted for statement 16A which states that energy can be used up as the appropriate response to question 16 gave the following explanations to qualify their choice.

S_1: We are able to walk because we have energy. When one runs out of energy one gets tired.

S_2: One has to have energy in order to be able to perform work.

Most of the students gave reasons which were the same as S_1's or S_2's though the wording was in other cases slightly different.

Summary View

The students seem to be clinging to the everyday life view that in order for one to be actively involved in the day to day activities, one should have energy. When one gets tired, it is said that one has run out of energy.

Question 19

Discussion

For question 19, the suitable response is statement 19A which says that the gravitational potential energy of a stone that is dropped from a height of 4m decreases as the stone is falling to the ground.

Table A reflects that 41,89% of the respondents in the student questionnaire analysis had the idea that the gravitational potential energy of a body increases as it is falling to the ground which is incorrect. The students who were interviewed supported their line of thought with the reasons that are going to follow.

S_1: As the stone is coming down, its speed increases.

S_2: The stone is coming down with more speed.

In Physical Science an increase in speed is associated with kinetic energy. These students must be confusing gravitational potential energy with kinetic energy, so might be the 41,89% in the questionnaire analysis.

Summary View

The students appeared to be confusing gravitational potential energy with kinetic energy.

Question 20

Discussion

Statement 20B which states that the weight of an object decreases as it is moved away from the centre of the earth is the appropriate/correct view.

In the interview process interesting reasons were given by the students who supported that the mass of an object decreases as an object is moved further away from the centre of the earth, that is, response 20C. This is an incorrect view.

S_1: The mass will decrease because when you take the reading from the spring balance at a higher level it will not be same as at a lower level.

S_2: As the object is moving further away, the object becomes smaller and smaller, for example when you look at an aeroplane when it is high up it is small.

S_3: When you throw a small stone up, you will not see it properly when it is up there. You will see it when it is coming down again.

Summary View

It seems that there are two misunderstandings of the scientific concepts of mass and weight.

a) The students seem to have the misconception that the mass of an object is the same as the weight of an object. Typically this is supported through the statement by S_1.

b) Since the weight of an object differs at different heights above sea level, the same applies to the mass of the object as well. This is reflected by reasons like "when an object is moved further away, it becomes smaller and smaller" or that "when a small stone is thrown up, one cannot see it properly when it is up there", implying that the stone has become smaller up there. This assertion is supported by both S_2 and S_3.

During the interview process some of the explanations given by the students to support their answers to the questions were not clear or understandable. These explanations have therefore been omitted in this section, but some of them will be reflected in appendix B.

4.3.2 Analysis of Category B responses

Table B

QUESTIONS	PERCENTAGES OR RESPONSES
1B	24,51
1C	28,98
2A	24,40
17A	29,11

Question 1

Discussion

The appropriate/correct choice in this question is response 1A and it states that there are two forces that are acting on a book that is lying on the table

Table B shows that 24,51% of the respondents were of the view that there are no forces that are acting on a book that is lying on the table, statement 1B which is an inappropriate/incorrect response. Some of the students (28,98%) took statement 1C which says, that the force of gravity is the only force acting on the book as the appropriate/correct view.

A discussion of the findings from the interviews to show why the students supported statements 1B and 1C is to follow. For all the students who were interviewed (individually), the following is a sample of the characteristic/typical responses.

Discussion of the analysis of response 1B

The analysis of results reflected that 24,51% of the students seemed to be having the incorrect thinking that there is/are no force(s) that is/are acting on a book that is lying on a table. There are two forces that are acting on the book, an upward and a downward force. The researcher then opted for the interview as he wanted to know why the students had this line of thinking.

The students who supported statement 1B furnished the following reasons or explanations to support their choice.

S_1 "There is no force that is exerted on the book" and emphasizing in Xhosa he said "Ihleli nje" meaning that it is just resting.

S_2 "The table has got no force and therefore it is wrong to say there is a force that is exerted on the book by the table".

S_3 "Akukhonto icinezele incwadi, ke i-force ayikho". This can be interpreted to mean that there is nothing that is exerting a force on the book and therefore there is no force.

S_4 "There is no force because the book is not moving".

S_5 "The table and the book are not moving, therefore there is no force".

The student S_2 did not accept that a stationary object like a table can exert a force. This view was also declared by S_3, S_4 and S_5. Student S_3 appeared to believe that only downward forces exerted by visible things/persons exist. Students S_1, S_4 and S_5 on the other hand seemed to be of the opinion that objects have to be moving in order to regard force as being exerted on objects.

Summary view of 1B

From the reasons given by the students, the researcher could deduce that the fundamental reasoning of the students was that if an object "has a force" the object has to be in motion. This is reflected in the explanations given by S_1, S_4 and S_5.

Discussion of the analysis of response 1C

Some of the students (28,98%) felt that there is only one force that is exerted on a book that is lying on the table, namely, force of gravity, which is incorrect. The correct statement is that "there are two forces that are acting on the book, the force of gravity (downward) and the force exerted by the table (upward)". The researcher had a duty then to find out why they had this incorrect view. The interview was the suitable instrument for this purpose as far as the researcher was concerned.

The students who supported statement 1C gave the following reasons:

S_1 "When a pen is thrown up it falls down because there is force of gravity, therefore even the book has force of gravity".

S_2 "The book cannot fly from the table because the force of gravity is dragging it down".

S_3 "When an object is having weight (force of gravity acts downwards on it), it cannot stay in the air. It comes down, but the table blocks it".

S_4 "There would be two forces (one of them acting upward) if we could be shown that when you put the book on the table it also goes up".

S_5 "The book is exerting a force on the table, and the book is not".

Interviewer : "Why do you say that the book exerts a force on the table?".

S_5 "If the book was heavy enough and the table was standing on soft ground the table would sink which shows that the book exerts a force".

Interviewer : "You said that the table does not exert any force on the book. Can you explain why?".

S_5 "If the table was exerting a force on the book, you should see the book moving upwards".

Students S_4 and S_5 seemed to base their argument on the fact that they could see a book falling down (which is a visible effect of the force of gravity), but could not see the visible effect (of a book moving upwards on its own) of a table exerting a force on the book. They seemed to think that in order to accept that the table exerts a force on the book, they should see a book moving upwards from the table. To them (students) this would be an indication that the table is pushing the book up. They seemed to be of the opinion that if the book had (possessed/owned) an upward force it would move up since there is nothing stopping it.

Summary view of 1C

It seems the students could accept that the book does "contain" a force (force of gravity) even when it is stationary because if the table could be removed the book would fall on its own. This is a clear indication of how the students accommodate the concept of gravitational force.

They seemed to have the conceptual frame-work that a body contains a force or there is a force inside a body.

Question 2

Discussion

Response 2B which asserts that there are two forces that are acting on a hanging block is the suitable choice.

The students who were for the incorrect idea (statement 2A) that there is only one force that is acting on a hanging block, that is, the downward force (force of gravity), gave the following reasons to support their response.

S_1 "It is because the block has its own weight that is dragging it down, that is why I say there is only one force that is acting on the block, the downward force (force of gravity)".

S_2 "If the wooden block could be untied, the block could come down, which shows that there is a downward force that is acting on the block".

S_3 "The wood exerts a force because it is in the air, and can come down any time the string breaks".

S_4 "When you are tying the rope on the block in order to hang it you have to hold it up because the force of gravity is pulling it down".

S_5 "The force is pulling it (the wooden block) down (force of gravity), but the string is holding it".

It seemed that as far as the students who were interviewed were concerned the wooden block would fall to the ground as soon as the rope breaks or is untied which indicates that the force of gravity is acting on the block. They seemed to regard the rope as merely holding the block from falling down, but could not see the rope as exerting an upward force on the block.

Summary View

The students seemed to be thinking that a hanging object could fall to the ground if whatever is holding the object could break or be untied. This seemed to be an indication to them that the force of gravity is acting on the object and is the only force that is exerted on the object.

The researcher thought that it would probably be worthwhile to note that 65,98% in question 2 support the correct idea that there are two forces that are involved compared to 46,15% in question 1, which is a similar question to question 2 (the two questions are comparable in physical situations). The students might have seen a possibility that the hanging block in question 2 might fall to the ground if the rope could break but could not have the same imagination in question 1.

The reasons given by the students in question 1 to support their choice of response 1C as well as the reasons given to support response 2A bear testimony to what has been argued or speculated in the previous paragraph. It is a fact that 23,47% in question 1 said that there are no forces that are acting on a book that is lying on the table, while only 9,62% in question 2, which is a similar case, indicated that there are no forces that are exerted on a hanging block. This indicated that some of the students who said that there are two forces that are acting on the book that is lying on the table in question 1 might have opted for the appropriate response in question 2 which states that there are two forces that are exerted on the hanging block.

The students seemed to be understanding that there are two forces that are acting on a hanging block as opposed to a book that is on the table. It would be better for a teacher when dealing with the case of two forces that are acting on a stationary object to start with the example of a hanging object and there after an object that is lying on the table. It would then be easier to understand the latter (forces acting on an object that is lying on the table).

Question 17

It is statement 17B which states that an apple that is lying on the table at a height of 1m above the ground does have gravitational potential energy that is the appropriate/correct view.

Some of the students (29,11%) regarded statement 17A to be the suitable statement. Interviews were conducted in order to find out why they (students) made this selection. Statement 17A asserted that an apple that is lying on the table that is 1m high above the ground does not have gravitational potential energy. In supporting their choice of statement 17A as the suitable response to question 17, the interviewed students furnished the reasons which are given below. Only a sample of the reasons has been used for reporting.

S_1: Because it is not hanging it was lying it has no gravitational force.

S_2: It is because it is not lying on the ground it is on the table.

S_3: It is lying on the table with no force.

Interviewer: "Can you explain further what you mean"

S_3: If it had a force it would fall to the ground.

S_1 seemed to be of the opinion that an object is said to be having gravitational potential energy if it is hanging, that is, if there was the possibility that the object might fall to the ground. Student S_2 appeared to be thinking that an object has gravitational potential energy when it is on the ground which is an inappropriate/incorrect thought. S_3 might be confusing gravitational potential energy with force (force of gravity)because he refers to the book as having no force when it is lying on the table. S_3 also seemed to be thinking that there are no forces that are acting on the book since it is stationary.

Summary View

The main finding in this case is contained in S_3's argument. The students who have the same thinking line as S_3 seemed to be

a) confusing gravitational potential energy with gravitational force

b) of the naive idea that there are no forces that are acting on a stationary body.

4.4. SECTION C

FINDINGS FROM LESSON OBSERVATIONS

This part of the research/investigation followed after the interviews with the students so as to examine further why the students had the inappropriate conceptions that have been revealed by the interviews.

As highlighted in the literature review Bell and Freyberg in Osborne and Freyberg (1992) have identified the following problems that may be encountered in a Science class.

a) If the teacher's language includes words unfamiliar to the pupils (students), which are not explained in the pupil's (student's) language, comprehension of what is being said will not occur. Pupils (students) simply fail to construct meanings from the teacher's flow of words.

b) Where the teacher's own concepts are inadequate there is unfortunately a greater likelihood that the teacher will consciously or subconsciously try to obscure his or her lack of understanding by the use of technical language, whether it be verbalised, written on the board, or referred from the textbooks.

Teachers were observed while teaching the concepts of **force** and **work**. This was done to find out

i) how the teachers handle the introduction of the concepts and

ii) whether the teachers do not contribute to the inappropriate frame works that the students seem to generally have.

When reporting the researcher will use T to represent teacher and S to represent student with S_1 referring to first student, S_2 to second student, and so on. Only those parts of the lessons that have significance to the present research study will be reported on, that is, those cases where the teacher showed signs of having inappropriate conceptions himself or herself which might be passed on to the students that were being taught.

4.4.1 Observation of the Teaching of the Concept of Force

This concept is introduced in standard 5, is not dealt with in standard 6, and then done again in more detail in standard 7.

a) In one of the standard 7 lessons that were observed the teacher showed signs of having an inappropriate conception as far as the concepts of mass and weight are concerned. The following extract from the lesson bears testimony to what has been cited:

T: "We are now to go to weight. There are two concepts mass and weight. We are going to show the difference between the two. If I say I **weigh or have a mass** of 70 kilograms, how can you explain the meaning of 70 kilograms?"

S_1: "It means the mass of the object"

T: "Weight is totally different from mass. It is the force that can be exerted by the earth on the object"

T: "What can you say about weight and force?"

There was no response from the students.

T: "Weight and force are the same. The unit of force is therefore the newton."

T: "Which instrument can you use to measure the weight of an object?"

S_1: No Reply

T: "Next"

S_2: "Spring balance"

The teacher started by saying: "If I **weigh or have a mass** of 70kg, how can you explain the meaning of 70kg?". Though the teacher wanted to show the difference between mass and weight, he still said one weighs 70kg when he intended to say one's mass is 70kg. This indicates that the teacher might be confusing mass and weight. The students are not likely to find anything wrong with saying that one weighs so many kilograms.

b) In the instance that is going to be cited the teacher seemed not to bother himself to try to find out from the students why they were giving the answers that they were giving.

T: "What is meant by force of gravity?"

S_1: "Force of gravity is a force that occurs outside".

T: "Next"

(The teacher asked another student without saying anything to the first student.)

S_2: Explained in Xhosa: "Xa uthathe ilitye liwe emhlabeni yiforce of gravity". This is translated into English as: When you take a stone and it falls to the ground, it is force of gravity.

T: "You have not explained the force of gravity"

The teacher passed on to S_3 who said: **"The force of gravity is the force of attraction of the earth on a body".**

The teacher accepted the answer. It seemed that the teacher was satisfied because this is exactly what is said in the textbook (that the force of gravity is the force of attraction of the earth).

When the student described the force of gravity as **"a force that occurs outside",** the teacher never bothered to find out from the student what he meant by that. Even in the case of the second student who said that **"when you take a stone and let it fall to the ground it is force of gravity"**, the teacher just said she has not explained force of gravity, though there was some substance in what the student was saying. The teacher appeared to be looking for explanations that would give the exact words used in the prescribed textbook.

An inappropriate conception of power and force was also detected during the course of the lessons that were observed. The teacher **said "the earth has got a pulling power to the object"**, when he meant to say the mass of the earth is responsible for the pulling force on the object/mass. The teacher in this case appears to have a problem in differentiating between **power** and **force.**

4.4.2. <u>Observation of the Teaching of the Concept of Work</u>

Some of the teachers do not want to discuss the scientific meaning attached to the concept words in comparison with the everyday life understanding of the words. This puts the students in a dilemma because they will be left on their own to compare the intuitive beliefs or naive views about the idea taught with the scientific meaning that is introduced by the teacher. The students might then lose the ability to think or communicate in the two domains of knowledge, that is, real lifeworld and scientific world and lack capability to distinguish between them.

The view illustrated above is portrayed in the following statement that was uttered by one of the teachers observed. This was a revision lesson and the teacher wanted to know whether the students remembered the scientific understanding of the concept **"work".**

T: "Who can tell me what the term **"work"** means? Don't tell me that washing dishes is doing work, that is not what I want."

The students' life world view of the concept work as a point of departure towards the introduction of the scientific view of the concept, was excluded by the teacher from the very onset through stating that they should not tell her that washing dishes is doing work. The teacher should differentiate between classroom meaning of the concept and home understanding of the word. A more acceptable approach would be for the teacher to explain to the students that in every day life understanding washing dishes is regarded as doing work, but in the scientific context work is done on an object if a force acts on it and it moves a certain distance.

The knowledge that the students have acquired from the environment in which they live cannot be done away with. Though the teachers are preparing students to be successful scientists, the students should still be able to communicate in every day life which is in agreement with Solomons (1983)'s view that **"Science students should never lose the ability to communicate"** (in every day life). The students should be able to comprehend remarks like **"wool is warm"** and **"we have used up our energy".** The students should also come to terms with the notion that although in every day life washing dishes is doing work, in a Physical Science class it is not.

4.4.3 Conclusion

From the observations above the researcher made the following deductions:

a) The teachers failed to give the students a chance to voice out their own opinions about the concepts concerned. They seemed to be looking for the textbook explanations when asking students questions. If students gave answers that were not what is in the prescribed textbook the teacher simply said: **"no"** and passed over to the next student. The teacher did not try to find out what the student was trying to say.

b) Teachers themselves appeared to be having certain inappropriate scientific conceptions with regard to the concepts that were taught which can be passed over to the students. The following two examples illustrate this observation:

   i) The teacher said an object **"weighs 70kg"** when he meant to say that the mass of the object is 70kg

   ii) Another teacher described the force of gravity as the earth's **pulling power** on an object. The concept of power was used inappropriately here. The teacher in this case might be using the words force and power interchangeably in everyday life. The teacher should learn to know when to use the scientific language and when the home language so as not to confuse the students. The teacher has the duty of making the students communicate in both the scientific and home language.

c) Normally Physical Science is taught in an experimental or illustrative way so that there should be interaction. Most of the lessons observed lacked this aspect. There should be an experiment/observation from which the scientific meaning of the concept may emerge.

4.5 SECTION D

FINDINGS FROM ANALYSIS OF THE PRESCRIBED TEXT BOOKS

This is the fourth stage of the research. Since the textbook is a powerful tool in the teaching and learning process, the researcher decided to analyse some of the textbooks that are recommended for the standard 7 level in order to establish whether the textbooks do or do not contribute to the findings obtained in the previous stages. Nine textbooks that are recommended for the standard 7 level, were analysed. The aim of this venture was to check:

a) how the textbooks handle the concepts concerned in encouraging the accepted scientific conceptual frame-work with regard to the concepts of force and work and energy.

b) whether they (the textbooks) do mention alternative frame works that the students may have emanating from the way they understand the words in everyday life.

The textbooks analysed are the following:

i)	Ayerst P.W. et al	(1995) :	General Science Standard 7 Shuter & Shuter, Pietermaritzburg, 3rd Edition
ii)	Cronje N.S. et al	(1994) :	General Science 2000 Standard 7 Nasou 1st Edition

iii)	Jansen E.G. and Dekker J.	(1987) :	Understanding Science Standard 7 Maskew Miller, Longman
iv)	Fourie D.I. et al	(1996):	Exploring General Science Standard 7 via Afrika, 2nd Edition
v)	Fourie D.I. et al	(1996):	General Science in Practice Standard 7 Afro Publishers, 1st Edition
vi)	Heyns G.F. et al	(1995):	Modern General Science Standard 7 Nasou, 3rd Edition
vii)	Scholtz D.A. et al	(1993):	Active General Science Standard 7 De Jager - Haum Publishers, Pretoria
viii)	Van Dyk J.J. et al	(1989):	General Science in Action Standard 7 De Jager - Haum Publishers, Preotria
ix)	Wessels H.J. et al	(1995):	New Era General Science Standard 7 Nasou, Cape Town

The handling of the concepts of force, work and energy was analysed. Only those parts of the textbooks that in the researcher's view may confuse the students or may lead to inappropriate understanding of the concepts concerned by the students are reported on.

4.5.1. Handling of the concepts of "force" in the textbooks

a) Jansen and Dekker (1987) assert that "**the principles of Science are not separate from everyday experiences**" and that "**to understand forces in everyday life, one needs to be able to identify the forces acting on a certain object**".

This statement might make the students think that the meaning that is attached to the concept word force in everyday life is necessarily the same as the way the concept of force is understood in Science.

For example there is a common incorrect conception that a moving object has an inherent force that is contained in it which is keeping the object in motion. For instance a ball that is kicked and rolls on a flat surface is regarded in everyday life as being kept moving by a force inside it that has been inherited from the kicker's foot. On the other hand in Physical Science a force that is exerted externally on an object cannot be transferred into the object. To expatiate further, a ball that is kicked and keeps on moving is not moving because the force exerted by the foot of the kicker on the ball has been transferred into the ball.

Secondly, there is a naive or intuitive belief, that comes from the students' understanding of the concept of force, that a moving object, like the rolling ball that has just been mentioned, comes to a halt because the force that was inherited and was therefore causing its motion, has been used up. As far as Physical Science is concerned, the frictional force which is acting in the opposite direction to the direction of motion of the object is the actual cause for the object to stop moving.

b) Jansen and Dekker (1987) say: **"Bathroom and kitchen scales or balances also contain springs and are therefore force meters. However, they are not marked in newtons, but in kilograms and grams".**

To say that **"bathroom and kitchen scales are force meters"** and at the same time say **"they are not marked in newtons, but in kilograms and grams"** might mislead the students to think that weight (force) can be interchangeably expressed in both newtons and kilograms. This would lead to a confusion of mass and weight.

The relationship between mass and weight (force) has been identified as a problem area, that is, the two concepts are confused, and are taken to mean the same thing. This problem has been picked up in the analysis of results, and also in the interviews and was also encountered during the lesson observations which means that both students and teachers seem to have difficulty in grasping this aspect. There is also the problem of bathroom scales which are graduated in kilograms, but used to determine weight in everyday life. If the textbooks do not explain explicitly the issue of the use of bathroom scales as force meters, the problem of expressing weight in kilograms in a scientific context might not be eradicated from the students as well as some of the teachers.

The life world views or naive ideas about force have not been catered for in all the textbooks that have been analysed. For example, in everyday life a moving object is taken to be having a force inside it that causes its motion (Thijs, 1992). The naive ideas like that there are no forces that act on a stationary object, for example, a book that is lying on the table, or that a passive object, like the table cannot exert force (indirectly cause a force to act on another body), should be mentioned in the textbooks so that the students might be made aware of the fact that the concept of force might have a meaning attached to it in everyday life which is inappropriate in a scientific context.

4.5.2. **<u>Analysis of the handling of the concept "work" in the textbooks</u>**

a) Scholtz et al (1993) say: **"When one works very hard at one's homework, one is doing just about no work".**

The researcher feels that it is contradictory to say **"one works hard on ones homework"** and at the same time say that **"one is just doing no work".** It should have been stated in no uncertain terms that when one is doing homework, the meaning is there and acceptable in the non-scientific everyday life that one is doing work, but as far as scientists are concerned work is done only if a force is applied and there is displacement of the object on which the force is exerted.

b) Van Dyk et al (1989) introduce the concept work by saying **"The term 'work' is often used incorrectly".** In the following examples the meaning of **'work'** is explained".

The above assertion appears to be declaring that the meaning given to the word **'work'** in everyday life is incorrect, the correct meaning is the one given to the concept in Physical Science.

As far as the researcher is concerned the students should be made aware of the fact that there are two different worlds, the everyday life world and the scientific life world. Ordinary people say work is done when washing dishes, digging in the garden, doing homework, and so on, but scientists regard work to have been done on an object when a force acts continuously on the object and the object moves a certain distance, where work is regarded as being the product of the applied force and the distance moved.

c) Scholtz et al (1993) assert that **"work is done on an object only when a force** acts over a distance, causing movement in the direction in which the force acts. Scholtz et al go on to say that when the **"displacement of the object** (that is, the distance which a body moves from start to finish) **due to the action of the force, is not in the same direction as that of the force, no work is done".**

Ayerst et al (1995) have a meaning for the concept of work, that is, **"work is done when a force acts through a distance on an object and the object moves in the direction in which the force is applied".**

The students will learn that: These statements are in contradiction to the established perspectives in Physical Science, that is,

a) the frictional force also invariably does work on a body in the opposite direction to that of motion and that is why the body eventually stops.

b) the force of gravity (acting downwards) does work on a body that has been thrown and is moving upwards.

c) when a body is moving down a slope the force that is acting on the object (force of gravity) is not in the same direction as the direction of motion of the object.

4.5.3 **Conclusions**

a) The existence of the everyday life meaning of the concepts, which may be different from the scientific meaning, is either mentioned in passing or not mentioned at all. In the book by Van Dyk et al (1989) it is said **"The 'term work' is often used incorrectly",** that is, in everyday life. The child who lives about ninety percent of his or her time out there in the life world (only 45 minutes to 1½ hours are spent in a Physical Science classroom) will be confronted with a problem of not knowing whether what he/she has learnt at home is correct or not. In order to avoid creating the problem that has just been highlighted, the textbooks should mention the existence of the two worlds, that is, the life world and scientific world. It should be stated in detail in the introductory remarks how the meaning of the words force, work and energy is viewed in everyday life and thereafter discuss the meaning given to the concept in Physical Science. The fact that these two worlds both exist and are running parallel to each other should be stated so that the students should be able to fit in both worlds. The students should be made to understand that they will use the everyday life meaning in the life world and the scientific meaning in the scientific world.

b) The textbooks seem not to be in a position to fulfill their role of being the main source of information for both the teacher and the student. The textbooks either have scanty information or have parts of the information put in such a way that it may bring confusion or inappropriate understanding at a later stage. For example saying that **"when one works very hard at one's homework, one is doing just about no work"**, might confuse the students as discussed in 4.5.2 (a). Sub-sections 4.5.2 (b) and 4.5.2 (c) also reflect this notion of textbooks that present information in a manner that may confuse students.

CHAPTER 5

SUMMARY OF THE MOST IMPORTANT FINDINGS, RECOMMENDATIONS, SUGGESTIONS FOR FURTHER RESEARCH AND GENERAL CONCLUSION

5.1 INTRODUCTION

5.2 SUMMARY OF THE MOST SIGNIFICANT FINDINGS

5.2.1 IMPORTANT FINDINGS AS FAR AS THE STUDENTS ARE CONCERNED

5.2.2 IMPORTANT FINDINGS WITH REGARD TO LESSON OBSERVATIONS

5.2.3 SUMMARY OF FINDINGS FROM TEXTBOOK ANALYSIS

5.2.4 CONCLUSIONS

5.3 LIMITATIONS OF THE PRESENT STUDY

5.4 RECOMMENDATIONS

5.5 SUGGESTIONS FOR FUTURE RESEARCH

5.6 GENERAL CONCLUSION

CHAPTER 5

SUMMARY OF THE MOST IMPORTANT FINDINGS, RECOMMENDATIONS, SUGGESTIONS FOR FURTHER RESEARCH AND GENERAL CONCLUSION

5.1 INTRODUCTION

Kyle (1995) in his editorial asserts that **"Science Education is concomitantly failing to keep pace with changes in society, including how citizens both acquire and use knowledge".** He goes on to criticise the continuing dissociation of school science from the daily life experience of the vast majority of students, in part because most school science courses are taught as a history of science.

What schools need to do is to produce enough students who will go into scientific or technological careers. Students who have enjoyed and appreciated school Physical Science will feel confident to take part in responsible decision-making as scientifically literate citizens.

Studies have found that students begin formal Science Education with a system of physical conceptions that differ in deeply systematic ways from those of the Science Educationists and present a significant obstacle to learning Physical Science. Alternative conceptions are not addressed, either in the Physical Science classroom or in Physical Science textbooks. Without the same conceptual framework as the teacher, students are unable to derive the intended meaning from instruction. What is taught in the Physical Science classroom and what is contained in the Physical Science textbooks should be presented such that it makes sense in the context of the students' own beliefs. Conceptual learning will then be encouraged.

5.2 SUMMARY OF THE MOST SIGNIFICANT FINDINGS

5.2.1 Important Findings as far as the Students are concerned

From the analysis of the questionnaires and interview the researcher observed that the students appeared to have the following misconceptions:

5.2.1.1 Incorrect Conceptions related to force

a) If an object is at a certain height above the ground and not moving, either there is no force that is acting on the object or there is only one force that is exerted on the object. In question one of the questionnaire (53,41% ($^{161}/_{301}$)either said that there is no force that is applied on the object or only the force of gravity is exerted on the object.

b) If an object is not moving no force is involved even if they are told that a force was applied but could not make the object move. They appear to think that force always has to bring about motion. The fact that 33,22% ($^{100}/_{301}$), as reflected in the analysis of question four, supported the above notion, is an indication that there is a problem in this area.

c) When a force is exerted on an object and results in motion, the force is implanted in the object and then when this internal force dissipates, the object comes to a halt. This is revealed by the explanations that the students gave during the interview session to support their choice of the statement that the ball that rolls and stops (as reflected in question three of the questionnaire), does so because the foot is not in contact with the ball anymore.

d) The force exerted on an object is always in the direction of motion [69,23% ($^{207}/_{299}$) of the respondents supported this idea as shown in the analysis of the responses to question 5 in Chapter 4].

e) Mass and weight have the same scientific meaning and therefore the units of weight must be kilograms. [40% ($^{120}/_{300}$) of the respondents indicated that the weight of the girl is 36kg, which is the mass of the girl, when responding to question 8.] The reason for the above response is reflected clearly in the explanations that the students who were interviewed gave to support their choice.

5.2.1.2 Incorrect Conceptions of work/energy

a) Work is done on an object only when a heavy object has been moved a certain distance. If the object is light no work is done on it even if the object has been moved a certain distance in the direction of the force that is exerted. The fact that 48,79% ($^{141}/_{289}$) of the respondents were of the opinion that there is no work done on a piece of paper that fell on the ground, in putting it back onto the table, in response to question 10, is enough evidence to support the above idea. The reasons given by the students to the interviewer for giving the above response are reflected in section B of Chapter 4.

b) Work is done on an object when an object has covered a certain distance even if there is no unbalanced force that is acting on the object. This results from the fact that they seem to take a moving object as having a force that is inherent in it. (The analysis of the results revealed that 53,40% ($^{157}/_{294}$) of the respondents regarded the suitable choice to question 11 as being that work is done on the ball when it passes point A and B; that is, between point A and B).

c) The work done on an object when it is carried from the bottom to the top of an incline (stairs) is given by the product of the force applied on the object and the actual distance covered from bottom to the top of the incline, instead of the height of the top of the incline above the ground level. (The analysis of the responses to question 14, as reflected in chapter four, showed that 62,30% ($^{190}/_{305}$) of the respondents selected an answer to the question that reflected a thinking pattern in keeping with the idea that is stated above).

5.2.2. Important Findings with regard to Lesson observations

a) It appears that some of the teachers have misconceptions themselves which they might transfer to the students in the process of imparting information to them during lessons. For instance one teacher said **"one weighs or has a mass of 70kg"** and another teacher talked of the **"pulling power of the earth"** when he meant to say the pulling force exerted by the earth.

b) When asking the students questions during the lesson, the teachers seem to expect the students to give them what they have told them or what the textbook says. This is reflected by their response to the students' replies to their questions. If the student does not give the answer that the teacher is expecting, the teacher simply says **"no"** and passes on to the next student until he or she gets a student who responds according to what the teacher regards as appropriate and as said in the textbook. Students' ideas seem not to be explored at all.

The teachers seem to be too much dependent on the information that is contained in the prescribed books. They appear to impart to the students the information they get from the textbooks as it is, that is, without any input from their side.

5.2.3. **Summary of Findings from Textbook Analysis**

a) The textbooks mention very little or nothing on how the concepts of force, work and energy are understood in everyday life-world before introducing the scientific meaning attached to the concepts. Van Dyk et al (1989) even say **"the concept 'work' is often used incorrectly** (in everyday life)" which implies that only the scientific meaning is the correct or acceptable meaning.

i) No misconceptions that the students may have with regard to the scientific understanding of the concepts of force, work and energy are mentioned.

ii) No preconceived ideas or beliefs that the students bring from home and its environment to the Physical Science class are highlighted.

c) Some of the textbooks have information presented in a manner that may cause misconceptions at a later stage. For example Scholtz et al (1993) and Ayerst et al

(1995) assert that **"work is done when a force acts on an object through a distance and the object moves in the direction in which the force is applied".** This statement contradicts the fact that frictional force invariably does work on the body in the opposite direction to that of motion, which is why the body stops.

5.2.4. **Conclusions**

a) The students appeared to be having certain misconceptions as far as force, work and energy are concerned.

b) Teachers may have a contributing factor to the misconceptions that the students have as revealed in the few cases where the researcher has observed lessons. The teachers showed signs of having misconceptions themselves and might pass them (misconceptions) over to the students they teach.

c) The textbooks prescribed for the students do not discuss any life-world understanding of the concepts to be learned. The student is then trapped between the life-world view and the scientific one.

The scanty scientific information that is reflected in the prescribed textbooks makes the textbook less effective as a secondary tool to the teacher in making the student understand the concepts in the language of the scientists. Since some of the students are not good listeners they depend solely on the textbook to supplement their Physical Science learning and a poorly written textbook fails in this regard. The manner in which information is presented in some of the textbooks is such that misconceptions might crop up at a later stage as discussed in the analysis of textbooks.

As indicated above it has come to light that Black students have serious problems with the scientific understanding and learning of scientific concepts. The teachers themselves might still be having preconceptions and misconceptions that they had while they were students. This means then that something must be done to alleviate the problem.

5.3 LIMITATIONS OF THE PRESENT STUDY

a) Since the materials with regard to this study were collected in 1994 / 1995, the findings of this investigation reflected the position at the schools during that period.

b) The investigation was limited to the problems experienced by Black South Afiican Standard 7 students in the King William's Town region in the learning and understanding of the Physical Science concepts of force, work and energy.

c) The test population consisted of 12 selected schools, since it would be impossible to visit all the schools considering the time limit of the study, the expenditure and the tedious nature of such visits. It might then not be possible to generalise the results for all Black students.

d) Since there are various types of measuring instruments available for gathering information, the researcher had to look only for those research methods or instruments that would be suitable for the present research study. After careful consideration and in view of the nature of the data required for the study, the researcher decided to select the structured questionnaire, structured interview, lesson observation and textbook analysis as data gathering instruments.

5.4 RECOMMENDATIONS

If Physical Science teaching is to be effective, it must encourage the kind of learning that leads to conceptual understanding. What current Physical Science must acknowledge is that students' beliefs about how the world works are more strongly held because their conceptual knowledge has been constructed over many years of experiencing the everyday world. Physical Science teachers are thus faced not just with getting students to construct new knowledge, but with getting them to construct this knowledge in the face of strongly held beliefs.

The researcher is strongly of the opinion that if the following suggested solutions to the problem could be implemented, the learning with appropriate scientific understanding of the Physical Science concepts could be improved.

i) Recognition of the everyday life meaning

The meanings that have been given to words in everyday life world should not be discarded when introducing the scientific meaning attached to the same words. One cannot run away from the fact that most words that are used to represent scientific ideas, like force, work, energy, power, are derived from every-day life. It should be highlighted that the words concerned have a certain meaning when used at home and another when used in a scientific sense. There should be an awareness of words that are used in Physical Science, that have a different meaning when used in everyday life. There needs to be a bridge between **"Home Science"** and **"School Science".** A glossary could be drawn up of some of the technical terms as used in Physical Science and contrasted with everyday usage.

Students should not be blamed for thinking the way they do. Their thinking trend is based on their cultural background and environment. There is therefore nothing wrong with the everyday usage of the concepts. About 80% to 90% of the students' time is spent in everyday life (the students spend only 45 minutes to 1½ hours a day doing Physical Science and the rest of the hours of the day are spent communicating in everyday life language) and it would be a very serious mistake to attempt to make the students take the everyday meanings of the words as being incorrect because when they are out of the classroom they will have to communicate in everyday life language. The only thing that teachers and textbooks should concentrate on, should be to bring out the difference between the meanings given to the words/concepts in these two worlds, that is, the everyday life world and the scientific world. Emphasis should be on trying to make the students see the difference and be able to separate the two so that they (students) may fit in both worlds.

ii) **<u>Use of Vernacular to reach the students</u>**

Using vernacular as a vehicle to enhance the understanding of a scientific idea could be of no harm at all, instead more scientific understanding of the concepts could be achieved. Fundamentally the researcher sees nothing wrong with reaching the students by using the vernacular, that is, Xhosa, in the present study, if the teacher keeps on going back to English. The teachers should be aware of the power of using the vernacular while being mindful of the fact that students write examinations in English. The words force and energy, should not be changed to vernacular when using vernacular, to explain a scientific idea. The teacher should rather say **"i-energy"** or **"i-force"** instead of saying **"amandla". "Amandla"** in Xhosa can either mean force or energy depending on the context in which the word is used. Using the word **"amandla"** would then bring confusion to students because they would not know whether it is referring to force or energy. It is very important to take note of the fact that the Xhosas are not confused at all when they use the word **"amandla"** in their language. They know exactly when it is referring to force and when it is referring to energy depending on the context in which it is used.

As English which is the medium of instruction in Black schools is a second language to the Black students, the students will first battle with understanding English as a language before they can understand the scientific idea that is explained. Means should therefore be devised so that the understanding of terminology will enhance the comprehension of the context of a scientific discussion.

Since Physical Science has strict rules unlike common day use of words, the appropriate scientific terminology should be demonstrated/illustrated through observation. It should also be explained in no uncertain terms that in Physical Science:

a) force is not used but applied on or acts on an object,
b) energy is not used, but transferred or changed from one form to another, and
c) one does not just say work is done, but refers to work done on an object.

iii) **Teacher In-service and what teachers should do**

Most of the Black teachers might have studied during their schooling under conditions where preconceptions and misconceptions were not attended to at all. If this is the case, they might therefore be having misconceptions themselves. To alleviate this problem the teacher-in-service learning centres should prepare courses which will be dealing with specific Physical Science misconceptions and how to handle them in a teaching situation. This will then equip the teachers in dealing with the problem.

Teacher manuals should be provided which will be dealing with misconceptions and how to handle them. Additional texts which would be dealing with misconceptions that students have as far as certain scientific concepts are concerned and how to handle them, should be introduced.

Having been exposed to the idea of preconceptions and misconceptions, the teachers should first consider what the students already know and understand about the concepts to be taught before they introduce the scientific meaning so that they can engage the students in activities that will assist them in constructing new meanings.

Physical Science teachers could achieve this goal by promoting class group discussions, which is where the preconceived ideas and misconceptions will come out. They should also try to analyse each statement that is given by a student as an answer to a question that has been asked by the teacher, be it in a class lesson, test or examination as sometimes the statements might reflect the preconceptions or misconceptions that the students have.

Having identified the preconceptions and misconceptions, the teacher will then be in a position to attend to them.

The teachers should not only be dependent on the prescribed textbook as a source of information. They should look for as wide a choice of reference textbooks/materials as possible so as to find out how other authors approach the scientific description of the concept concerned. They should also embark on enriching themselves by paying frequent visits to libraries to discover what new information, through research studies, is available on the teaching of the Physical Science concepts that they are dealing with at that particular level of education.

iv) **Recommended Textbooks**

Since both the teachers and students tend to regard the textbook as the main source of information, textbooks that discuss misconceptions, should be made available to the students and teachers so as to make them aware of the misconceptions encountered when learning certain Physical Science concepts.

Textbooks that are recommended for use by the students should have a glossary at the back that will give simplified explanations or descriptions of the difficult words or terms that the students will meet when reading through the textbook. This will make it possible for the student to understand the terminology used in the textbooks thereby minimising chances of inappropriately understanding the given scientific explanations which would then lead to misconceptions.

The number of new concepts or words that are introduced per chapter of the textbook should be minimised so that the students should be able to assimilate them with less problems. In other words the textbooks should not be loaded with more information than the students can comprehend in the given standard.

v) **Use of worksheets**

Worksheets are papers or booklets with tasks to be performed. The apparatus and procedure to be followed for the task is explained in detail. During the course of performing the task/experiment questions are asked in order to find out whether the student has observed, learned and conceptualised the ideas the task is intended to put through to the student. The answers to the questions are recorded on the worksheet.

Introduction of student work-sheets more especially at the lower levels like standard 6 and 7 would be very beneficial in improving scientific understanding of the Physical Science concepts that are taught at these levels as they would make the students more participative and able to capitalise on observation leading to conclusions in order to maximise conceptualisation. The teacher on the other hand would be able to monitor step by step how much the students understand.

The following points will clarify more why the researcher recommends the use of worksheets at the lower levels like standard 7.

a) Work-sheets will side track the English understanding problem as well as the reading problem. In worksheets students will be actively involved and will therefore be able to understand the concept better with minimal language problems.

b) The teacher will be able to pick up the misconceptions that the students have from how they interact with the practical situation. Learning in a practical way provides a conceptual framework that is scientific.

c) Since learning should be learner driven, students should be made the main participants in the learning situation and practical work and work sheets can provide that opportunity more than the reading of books.

d) In a worksheet and the questions that follow, the teacher has an opportunity to guide and redirect the students and in the course of that process learning unfolds.

Using a textbook implies that the students have proper reading skills which most of them do not have, especially those students whose mother tongue is not the medium of instruction. Examples of what can be contained in a student work sheet will be shown in the following pages.

EXAMPLE OF A WORKSHEET ON FORCE

TITLE: **Using a spring balance and bathroom scale to measure force or weight.**

OBJECTIVE:

i) To famialirise the students with the use of a spring balance to determine weight and to make them discover that the weight of 100g is 1N.

ii) To make the students understand weight better and also be able to differentiate between weight and mass.

APPARATUS: pen; book; 50g; 100g and 1kg mass pieces.

PROCEDURE:

i) Use a spring balance to measure the weight of the 50g, 100g and 1kg mass pieces.

ii) Use the spring balance to determine the mass of your pen and textbook.

Also tabulate your results as indicated below:

i)

OBJECT	MASS	WEIGHT
50g		
100g		
1kg		

ii)

OBJECT	WEIGHT
pen	
book	

OBSERVATION: Compare the mass and height of each of the mass pieces in (i) and say what relationship you notice between the values of mass and the values of weight.

CONCLUSION: You must have noted that weight = **Mass X ....**

TASK: Now determine the mass of the pen and the textbook from the weights you have determined and display your findings using the following format.

OBJECT	WEIGHT	MASS
pen		
book		

EXAMPLE OF A WORKSHEET ON WORK/ENERGY

TITLE: **How to calculate work done in carrying an object up an incline (stairs).**

OBJECTIVE: To check whether the students are not going to use the actual distance moved in determining the work done.

APPARATUS: Stairs, 50N bookcase, measuring tape.

PROCEDURE: Go to the flight of stairs and measure.

a) the distance from the bottom of the stairs to the top of the stairs.

b) the distance from the bottom of the stairs to the wall.

c) height of the stairs.

d) take the 50N bookcase from the bottom of the stairs to the top of the stairs.

RESULTS:

a) Distance from the bottom to the top of the stairs is ....

b) Distance from the bottom of the stairs to the wall is ....

c) Height of the stairs is ....

CONCLUSION: The work done on the bookcase as it is carried from the bottom of the stairs to the top of the stairs is ....

vi) <u>Restructuring the syllabi/order in which concepts are introduced</u>

The concepts of force and energy are first introduced in standard 5 and are not mentioned at all at standard 6 level. It is in standard seven where they are taught again. The introductory part that deals with force in standard 7 keeps on referring the students to the previous work which they are expected to recall though it has been done more than a year ago (that is, in standard 5). The researcher is of the opinion that, the discontinuity or break in the teaching of the concepts has a detrimental effect in the scientific learning and understanding of the concepts. He is of the idea that the concepts of force and energy should be included in the standard 6 syllabus together with the concepts of work and power. At this level (standard 6) only the relationship between the concepts should be discussed, but the everyday life understanding and scientific understanding of the concepts should be discussed at length at this level (standard 6). It is in standard 7 where the units used and the calculations involved with regard to the concepts should be discussed.

vii) <u>Employment of more Physical Science Advisors/Supervisors</u>

The Department of Education should embark on employing Physical Science subject-matter supervisors. These should be qualified individuals who have the content and pedagogical expertise and personality traits to communicate effectively with their colleagues and students. The identified persons should also have a strong desire to provide leadership and commitment in developing quality Physical Science programs.

viii) <u>Furnishing of schools with well equipped laboratories</u>

Schools, especially rural ones, should be provided with well equipped laboratories because Physical Science cannot be taught effectively without practical work

5.5 SUGGESTIONS FOR FUTURE RESEARCH

a) The researcher has noted that not much research has been done on misconceptions involving the concepts of force, work and energy with regard to Black South African students and he therefore appeals to future researchers to explore this area.

b) In this study not much has been investigated on misconceptions as far as energy is concerned. The investigator would love to see more research studies undertaken which would involve South African Black students in this field too.

c) Researchers should also embark on trying to bring to light preconceptions and misconceptions that South African Black students might be having with regard to other Physical Science concepts not mentioned in the present study, like pressure, light, and so on.

d) Though language of instruction (English in the present study) was not part of the research study it was noted that a second language as a medium of instruction did cause learning problems. The researcher therefore suggests that this area be researched.

5.6. GENERAL CONCLUSION

The research findings as revealed in Chapter 4 make the researcher confident that the present research study has accomplished its main goal of establishing that students bring to the learning situation preconceived beliefs or preconceptions. It has been found that the preconceptions that the students bring to class from everyday life world or misconceptions that students appear to have after being taught, end up affecting the learning and understanding of Physical Science concepts of force, work and energy.

The researcher feels strongly that in order to prepare with success future Black scientists, this field of preconceptions and misconceptions in the learning and understanding of Physical Science concepts should be given special attention.

BIBLIOGRAPHY

1. Ayest P.W.,Botha T.C.L., Dube V.K. and Ehlers M.J. (1995): General Science 7, Shuter and Shuter. Pietermaritzburg, 3rd Edition; p.56-69.

2. Appleton K. (1993): "Using theory to guide practice: Teaching Science from a Constructivist Approach". School Science and Mathematics Vol.93(5) p.269-274.

3. Best J.W. (1984): Research in Education. 4th Edition Englewoood Cliffs, New Jersey. Prentice-Hall Inc. p.165

4. Bybee R.W. (1994): Invited papers. The Science Teacher 62(1) p.8.

5. Cronje N.S., Ziervogel A., Brookes D and Commaille R.R. 994): General Science 2000 Standard 7. Nasou 1st Edition. p30-38 , 43-51.

6. Driver R. (1989): "Students' Conceptions and the Learning of Science". Int. J. Sci. Educ. Vol II, Special Issue p482.

7. Driver R. (1991): The Pupil as Scientist? Open University Press Milton Keynes. Philadelphia.

8. Driver R., Leach J., Scott P., and Wood-Robinson C. (1994): "Young people's Understanding of Science Concepts:Implications of cross-age studies for Curriculum Planning". Studies in Science Education Vol.24 p.75-100.

9. Dykstra D.I, Boyle C.F., and Monarch I.A. (1992): "Studying Conceptual Change in Learning Physics". Science Education Vol. 76 (6) p.615-622.

10. Fox D.J. (1969): The Research Project in Education. New York. Holt, Richard & Winston p.545

11. Fourie D.I., Kaske C.E.M.E., Wessels B.J. and Van Huissteen B.J. (1996): Exploring General Science Standard 7. Via Afrika, 2nd Edition. p2-19.

12. Fourie D.I., Fraser W.J., Mbekele V.L., Craig D., and Mc Farlane M. (1996): General Science in Practice Standard 7. Afro Publishers 1st Edition p.52 - 71.

13. Groves F.M. (1991): Science Vocabulary Load of Selected Secondary Science Textbooks. School Science and Mathematics Vol. 95(5) p231-234.

14. Hand and Treagust D.F. (1991): "Student Achievement and Science Curriculum Development using a Constructivist Framework". School Science and Mathematics Vol. 91(4) p172-176.

15. Heys G.F., de Villiers G., Gibbon D.B. and Fowler W.G., (1995): Modern General Science Standard 7. Nasou 3rd Edition p37-46.

16. Howe A.C. (1996): "Development of Science Concepts within a Vygotskian Framework". Science Education Vol. 80(1) p 35 - 51.

17. Jansen E.G. and Dekker J (1987): Understanding Science 7. Maskew Miller Longman.

18. Jiya Z. (1990): Students' Conceptions of Simple D.C. Electricity Circuits; A Study of Primary, inappropriate conceptions, learning difficulties of physics students, and implications for instruction. Rhodes University (Unpublished PhD. Thesis) 7, p.115 and 117.

19. Kahn M., Levy C., and Rollnik S. (1994): NEPI Working Paper : Science Education Policy : Issues and Proposals. University of Witwatersrand. NECC. P.11, p.14-27.

20. Kruger C., Palacio D., and Summers M. (1992): "Surveys of English Primary Teacher's Conceptions of Force, Energy and Materials. Science Education Vol.76 (4) p.343 - 346.

21. Kyle W.C. (1995): "Editorial: Scientific Literacy: Where do we go from Here?" Journal of Research in Science Teaching. Vol 32 (10) p1007 - 1009.

22. Licht and Thijs D.G. (1990): "Method to trace Coherence and Persistence of Preconceptions". Int. J. of Sc. Educ. Vol. 12(4) p403 - 416.

23. Millar R. (1989): Understanding Physics, Unwin Hyman London. p 59-66.

24. Orsborne R. and Fryberg P. (1992): Learning in Science: The Implications of Children's Science. Heinemann; Hong Kong.

25. Benchop M. and Ottevanger W. (1995): Supporting Curriculum Changes in the Classroom: Can materials make a difference? Saarmse Third Annual Meeting January 1995.

Cape Town. South Africa Vol.2.

26. Preece P.F.W. (1984): 'What to do with Science Misconceptions.' Science Education. Vol. 74(5) p 535

27. Scholtz D.A., Thomas A.M.L., Degenaar J.P., Muller C.J., and Brand J.H.P. (1993): Active General Science Standard 7. De Jager-Haum Publishers. Pretoria. p122-144.

28. Scopes P.G. (1973): Mathematics in Secondary Schools:A Teaching Approach. Cambridge University Press. London p. 124-125

29. Strube P. (1988): "The Presentation of Energy and Fields in Physics Texts". Physics Education. Vol. 23.

30. Thijs D.G. (1992): "Evaluation of an Introductory Course on Force" considering Students' Preconceptions", Science Education. Vol 76 (2).

31. Trumper R. (1990): "Energy and a Constructivist way of Teaching". Physics Education Vol. 25 p209 - 211.

32. Van Dyk J.J., Snyders W.P.C., and Schroeder W.A. (1989): General Science in action. Standard 7. De Jager- Haum Publisher. Pretoria p211 - 232.

33. Wessels H.J., Prinsloo M.L., Oosthuizen M.J., and Muller G.J. (1995): New Era General Science Standard 7. Nasou. Cape Town. p.44-52.

34. Wildy H and Wallace J. (1995): "Understanding Teaching or Teaching for Understanding: Alternative Frameworks for Science Classrooms". Journal of Research in Science Teaching. Vol 32(2) p 143-156.

35. Yager R.E. and Lutz M.Y. (1995): "STS to enhance Total Curriculum". School Science and Mathematics Vol. 95 (1).

36. Young P.V. (1956): Scientific, Social Survey and Research. New York. Prentice Hall. p.177.

APPENDIX A

SCIENCE EDUCATION QUESTIONNAIRE

NAME :

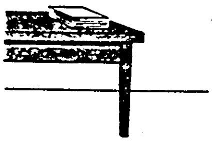
THE MULTIPLE CHOICE QUESTIONS ASKED IN THIS QUESTIONNAIRE WILL BE USED AS PART OF A RESEARCH PROGRAMME AND NOT FOR THE PURPOSE OF A CLASS TEST.

THE QUESTIONS ASKED REQUIRE A SCIENTIFIC VIEW OR UNDERSTANDING. THERE ARE THREE POSSIBLE ANSWERS TO EACH QUESTION ASKED. PLEASE RESPOND TO EACH QUESTION BY CIRCLING THE LETTER NEXT TO WHICH THE RESPONSE THAT SEEMS MOST SUITABLE TO YOU IS WRITTEN e.g. A: (B) : C IF YOU FEEL THAT B IS THE CORRECT ANSWER.

e.g. The M.E.C for Education in the Eastern Cape is A: Mr Jacobs (B) Mrs Balindlela C: Mr Bengu.

IF YOU FEEL THAT MORE THAN ONE ANSWER IS SUITABLE CIRCLE ALL THOSE THAT ARE SUITABLE, THAT IS IF, A and B are suitable, circle A and B, ie; (A): (B): C

1.



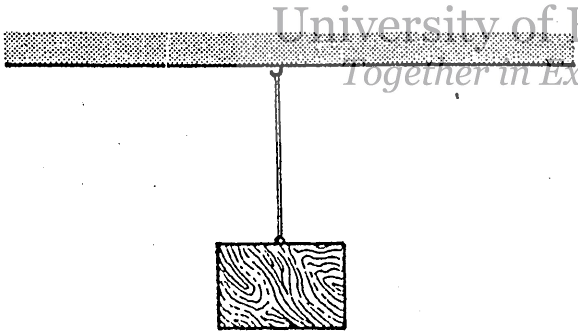
The figure above shows a book lying on the table.

A. There are two forces acting on the book, that is, the downward force of gravity and the upward force exerted by the table on the book.

B. There are no forces acting on the book.

C. Only the force of gravity is acting on the book.

2. In the figure below a wooden block is shown hanging from a string.



Which statement explains completely what is happening above.

A. There is only one force acting on the block, that is, the downward force due to force of gravity.

B. There are two forces acting on the block, namely, the upward force due to the tension in the rope and the downward force of gravity.

C. There are no forces acting on the block.

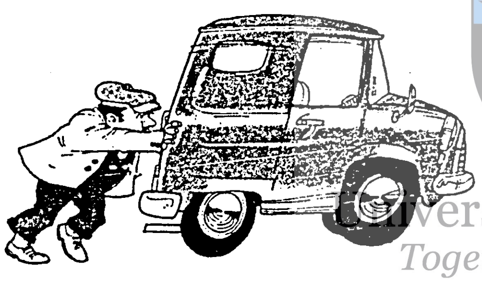
3. A ball is kicked, rolls on the ground and then stops moving eventually. The reason why it stops moving is because:

A. the foot is not exerting a force on the ball anymore.

B. of the frictional force which is acting in opposite direction to the motion of the ball.

C. of neither A nor B.

4.



The man is pushing the car and the car does not move.

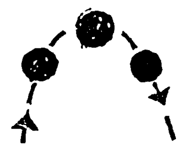
With regard to the above diagram which of the following statements are true.

A. Only one force is acting on the car, that is, the pushing force from the man.

B. Four forces are acting on the car, namely, the pushing force from the man, the frictional force, the force of gravity, and the upward force exerted by the ground on the car.

C. no forces are acting on the car.

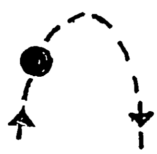
Question 5,6 & 7 are based on the following figure:



A ball is moving in an upward direction into the air and then falls back to the ground as shown in the figure.

N.B. In the figures below, the arrows indicate the direction of the force.

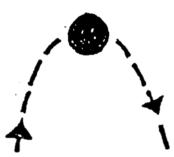
5. As the ball is going up, which of the following is true about the force that is acting on the ball?



A.  B.  C.  no force.

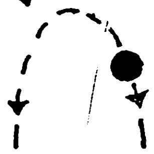
6. As the ball is just at the top of its flight, the force acting on the ball is shown in

A.  B.  C.  no force



7. If the ball is on its way down, the total force acting on the ball is shown in

A.  B.  C.  no force.



8. The mass of the girl is indicated as 36 kg on a bathroom scale. Her weight is:

A. 36 kg

B. 360N

C. 36N

9. A man pushes a wall with a force on 800N, but the wall doesn't move.

The work done by the man, in a Scientific sense, is:

A. 800N

B. 800J

C. OJ

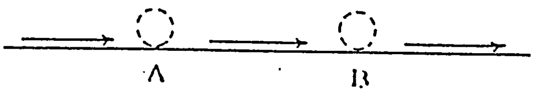
10. In which of the following cases is there no work done on the object in scientific sense?

A. A piece of paper that fell on the ground is put back on the table.

B. A pocket of potatoes is lifted from the ground onto the back of a truck

C. A student who has his book bag (ubhaka) on his back walks a horizontal distance of 20m.

11. A ball is moving on a flat surface with constant speed past point A and B. As indicated in the diagram below.



.ball moving towards point A

Is work done on the ball between A and B?

A: In the time between A and B there was no work done on the ball because there was no horizontal force acting on the ball.

B: Work was done because the ball has moved between A and B.

C: Not enough information is given in order to decide whether work is done or not.

12. A ball is allowed to fall on its own from a height of 4m above the ground. Is there any work done on the ball as the ball falls?

A. Yes

B. No

C. Not sure.

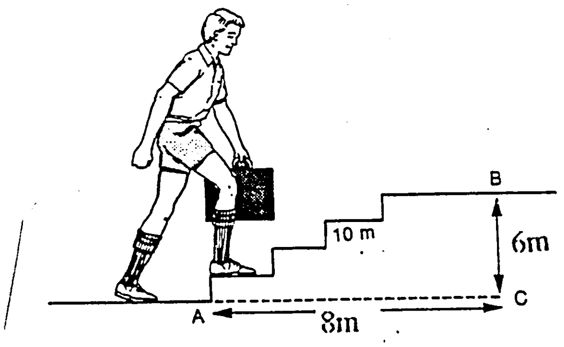
13. Has work been done in unscrewing (opening) a lid of a bottle?

A. Yes

B. No

C. Not sure

14. In the figure below, a boy is shown carrying a load up the stairs.



A boy carrying a load up the stairs.

The boy exerts a force of 100N in carrying the load up the steps from point A to B.

The work done by the boy is:

A. 100N X 6m

B. 100N X 8m

C. 100N X 10m

15. Which of the following statements is scientifically true about fuel (petrol) and food.

A. Fuel is a type of energy.

B. Food is a type of energy.

C. Fuel and food are sources of energy.

16. Scientifically speaking, which of the following statements concerning energy is correct?

A. Energy can be used up sometimes.

B. Energy can never be destroyed.

C. Energy can never be created.

17. Does an apple that is lying on the table with a height of 1m above the ground have gravitational potential energy?

A. No

B. Yes

C. Not sure.

18. Does an apple that is hanging from a branch of a tree 2m above the ground have gravitational potential energy?

A. No

B. Yes

C. Not sure

19. When a stone is dropped from a height of 4m to fall to the ground:-

A. the gravitational potential energy of the stone decreases as it is falling to the ground.

B. the gravitational potential energy increases as it is falling to the ground.

C. the gravitational potential energy remains the same as it is falling to the ground.

20. As an object is moved further away from the centre of the earth

A. the gravitational potential energy of the object decreases.

B. the weight of the object decreases.

C. the mass of the object decreases.

APPENDIX B

Appendix B reflects some of the unclear or not understandable explanations or reasons that were supplied by the students in the Pilot study questionnaire to justify their choices of responses per question. Only those questions in which reasons were furnished will be included in this annexure.

The explanations are given per choice or response and per question. S_1, S_2, and so on will be used to represent student 1, student 2, and so on. S, only represents student.

Question 1

Chosen statement : C

Reasons given:

S_1 : "There is only one act on a book".

S_2 : "The book have got power and force it easily to come down".

S_3 : "It comes from downwards to upwards".

S_4 : "The force of the book on the table".

S_5 : "There is no force above the book is only the book that have force".

S_6 : "Because the book take place on the table".

S_7 : "That force coming from the table to the book was the only force which is the force of gravity".

S_8 : "The book is exected to the ground".

Question 2

Chosen statement: A

Reasons given:

S_1 : "When you take that block with string it goes down and it would be the force of gravity".

S_2 : "Because the block is the downward force and block hanging down so is a force of gravity".

Question 3

Chosen Statement: A

Reason given:

S_1 : "Because that force where kicked a ball by a man is stop".

S_2 : "It is not kicked and stopped for itself".

S_3 : "The foot will never exert a force on the ball".

S_4 : "They do not kick the ball with force".

S_5 : "The ball controls itself".

Chosen Statement: B

Reasons given:

S_1 : "The friction force end and the ball could to stop".

S_2 : "If we kicked a ball it move at that certain time it stops".

S_3 : "If we kicked the ball they are moving".

Question 4

Chosen Statement: A

Reasons given:

S_1 : "The is a force when you push a car there is a pulling force and the man has got a force of pushing".

S_2 : "The force is that the man where waist about our force because the car does not move".

Chosen Statement: B

Reasons given:

S_1 : "By the time the man is pushing the car its a force, the car is not moving that the force of gravity".

Question 5

Chosen Statement: A

Reasons given:

S_1 : "Because the force is coming down pushing the ball upwards".

S_2 : "The ball has a force of upward".

Question 7

Chosen Statement: B

Reasons given:

S_1 : "The force is acting on the ball and the ball go on its way down".

S_2 : "There is no force when the ball is not kicking".

Question 10

Chosen Statement: A

Reason given:

S : "Because there is no sence in the piece of the paper that fell on the ground".

Question 11

Chosen Statement: B

Reason given:

S : "Because the ball moves on the way".

Question 12

Chosen Statement: B

Reason given:

S : "When you are standing on the throw a ball down, it is no necessary to be 4m".

Question 13

Chosen Statement: C

Reason given:

S : "Because it has screw".

Question 14

Chosen Statement: C

Reasons given:

S_1 : "Because the boy is done the work and took 100N to 10 m from the ground".

S_2 : "Because force is formed by Newton-meter".

S_3 : "The is a force that do buy a man can go up".

S_4 : "He is working with force to climb the stairs".

Question 15

Chosen Statement: B

Reason given:

S : "You time the man".

Chosen Statement: C

Reason given:

S : "Because the is not survive fuel and food".

Question 16

Chosen Statement: A

Reasons given:

S_1 : "Energy can something that must you need".

S_2 : "Energy is always present".

S_3 : "Because energy we do not want sometimes we want everything".

S_4 : "Because everything we did it by energy we will never do it sometimes".

S_5 : "Energy can something that must you need".

S_6 : "Because we are not used energy for sometimes, kanti (but) it is the ability to do work".

Chosen Statement: C

Reasons given:

S_1 : "We can store energy in tanks so that man under water can use it".

S_2 : "Because the is no food no water acting on the surface".

Question 17

Chosen Statement: A

Reasons given:

S : An apple cannot have height of 1 m.

Chosen Statement: B

Reasons given:

S_1 : "It stand in the table".

S_2 : "Because potential energy is anywhere".

S_3 : "Because it is nearly to the ground".

S_4 : "Because an apple must take place on the table".

Question 19

Chosen Statement: A

Reasons given:

:S_1 : "It breaks into pieces".

S_2 "Its not going to that unit it is going to decrease".

Chosen Statement: B

Reasons given:

S_1 : "The is gravitational that stone where fall".

S_2 : "The stone will quickly fall as it falling to the ground".

Chosen Statement: C

Reasons given:

S : "It is not broken, it will remain the same".

Question 20

Chosen Statement: B

Reasons given:

S : "It the space".

APPENDIX C

A collection of the explanations or reasons that were given by the students to qualify their choices which were not clear or understandable to the interviewer are furnished in this section. The reasons will be tabulated as in appendix B. The reasons were given in vernacular and will therefore be reported verbatim followed by the investigator's translation thereof.

Question 1

Chosen Statement: A

Reason given:

S : "Kungokuba xana ubeka incwadi phezu kwetafile iye yenze iforce".

It is because when you put a book on the table, it makes a force.

Chosen Statement: C

Reasons given:

S_1 : "Kungokuba umhlaba wonyuswa ngeforce of gravity".

It is because the ground is pushed up with the force of gravity.

S_2 : "Kungokuba amandla encwadi athathe indawo kwitafile".

It is because the force of the book has taken place on the table.

S_3 : "Kuba kaloku inye incwadi".

Because there is only one book.

S_4 : "Kuba incwadi ikwihorizontal place".

Because the book is on a horizontal place.

S_5 : "I-force of gravity yencwadi idibene neyetafile".

The force of gravity of the book has mixed with the table's.

Question 2

Chosen Statement: A

S : "Kungokuba xana uthatha ilitye ulibeke phantsi liye lihle phantsi lenze iforce of gravity".

It is because when you take a stone and put it down, it goes down and makes a force of gravity.

Chosen Statement: C

Reasons given:

S : "Kufana xa udibanise u + no - akukhonto yenzekayo".

It is like when you combine + and -, nothing happens.

Question 3

Chosen Statement: A

Reasons given:

S_1 : "Kungokuba iforce ayiyanga ngokwaneleyo kwibhola".

The force did not go enough to the ball.

S_2 : "Akunakukwazi ukukhaba ibhola ungazimiselanga".

You cannot kick a ball if you are not willing.

S_3 : "Kungokuba xana ukhaba la bhola kusuba uyikhaba une-force".

It is because when you kick that ball, you kick it personally having a force.

S_4 : "Inyawo alinayo iforce kuba ibhola ngeyihambe phezulu".

The foot has no force because the ball would have gone up.

S_5 : "Inyawo alidibenanga ne-force".

The foot has nothing to do with the force.

Chosen Statement: B

Reasons given:

S_1 : "Kungokuba kukho umoya ngoku ihamba ndawonye.

S : "Kungokuba akunakukwazi ukukhaba ibholo ihle ibheke ezantsi".

It is because you cannot kick a ball downwards.

Question 7

Chosen Statement: B

Reason given:

S : "Ininzi iforce eyenzekayo xa ibhola isiya ezantsi".

There is a lot of force that is taking place when the ball is moving downwards.

Question 8

Chosen Statement: A

Reason given:

S : "Nokuba iphumile ebathroom ayitshintshi i-weight yayo".

Even when she gets out of the bathroom, her weight will remain the same.

Question 10

Chosen Statement: A

Reason given:

S : "Kungokuba amandla ephepha aphelile".

It is because the force of the paper has dissipated.

It is because there is wind and it is now moving at the same place.

S_2 : "Amandla aphele emoyeni"

The force has dissipated in the air or wind, or the force has vanished in thin air.

Question 4

Chosen Statement: B

Reason given:

S_1 : "Kungokuba amandla engekho emhlabeni"

It is because the force is not on the ground.

S_2 : "Kungokuba umhlaba awufuni ihambe la moto. Imoto inamandla ngaphezu komntu:.

It is because the ground does not want the car to move. The car has more force than the man.

Chosen Statement: C

Reason given:

S : "Kungokuba akukho force yenzekayo".

It is because there is no force that is taking place.

Question 5

Chosen Statement: A

Reason given:

Question 14

Chosen Statement: C

Reason given:

S : "Kuba uzukadibanisa la-force yalankwenkwe, iload yayo kunye neziteps".

Because you are going to add the force of the boy, its load and the steps.

Question 17

Chosen Statement: A

Reason given:

S : "Kuba i-apile alinayo iheight".

Becasue the apple has no height.

Chosen Statement: B

Reason given:

S : "Ewe inayo noba yi - 1cm".

Yes, it is having it. Even if it is 1cm.

Question 19

Chosen Statement: C

Reasons given:

S_1 : "Alizokuthi ngokusuka liphoswe emhlabeni i-weight yalo ihle".

Its weight is not going to decrease only because it is thrown to the ground.

S_2 : "Ewe iyancipha kuba lifika lophuke".

Yes, it decreases because when it reaches there, it breaks.

S_3 : "Kuba i-energy iyafana naxa iwile".

Because the energy is the same as when it has fallen down.