AN INVESTIGATION OF THE CHALLENGES FACING GRADE 10 SCIENCE LEARNERS IN SENSE-MAKING OF MECHANICS PROBLEMS: A CASE STUDY

By

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Declaration

This research represents original work by the author and has not been submitted in any other form to another university. Where use was made of the work of others, it has been duly acknowledged in the text.

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Signature Date

Dedication

This research is dedicated to Nombongo, my wife and Mthokozisi and Njabulo, my sons. They are the best thing that has ever happened to me.

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Abstract

The research study was conducted at Ixopo High School, an English medium, former model-C, co-educational school in Kwazulu-Natal. The research is located within an interpretive paradigm and is informed by the constructivism theoretical framework. The learners and educators who participated in this research study did so voluntarily.

The principal objective of this case study was to investigate the challenges faced by 30 Grade 10 Science learners in understanding the problems posed in the mechanics section of the Physics syllabus. This investigation was carried out using two learning strategies: problem solving and practical work.

Various authors have noted some sections in the Physics syllabus are often misunderstood by the learners, for different reasons. From the literature and from the author’s personal experience it was found that mechanics is a topic that the learners of different races and age groups find difficult to conceptualise.

In general, learners have misconceptions and make errors in Physical Sciences. Often educators view children’s errors and misconceptions in terms of low intelligence, low mathematical aptitude, perceptual difficulties or learning disabilities instead of attempting to discover the real causes of the errors. Educators need to find out why the learners make these mistakes, in order to help them.

In most cases Mathematics forms a basic common element in scientific study. Hence, science learners need to be able to deal with numbers, operations, symbols and mathematical formulae. The term “science” embraces a very wide area of subject matter. Different learners will have widely differing interests within the many subdivisions of this field. This presents a problem when preparing learners for the scientific language they will need to study different branches of science. This implies that failure to understand the meaning of words or symbols inevitably impairs communication.

The data analysed was collected using a variety of data collection tools. The main data generation tools were science tasks, structured interviews and group interviews and questionnaires. The analysis revealed that learners were lacking in mathematical skills and science register (terminology). Both first and second language English speakers encountered problems in science register but the study found that the problem was more pronounced in the latter.

The findings of this study also highlighted that learners understand how to think mathematically when they are resourceful, flexible, and efficient in their dealing with new mathematical problems in mechanics. However, mathematical problem solving performance is built on the foundation of basic mathematical knowledge.

The study suggested that even when the challenges of a general understanding of English as the medium of instruction and scientific language (register) are overcome, learners are still challenged by mathematical problem solving strategies; reading and writing of science; making meanings of symbols and signs; graphs and scientific mathematical equations in sense making of mechanics problems.

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Chapter One

Introduction and Overview

1.1 Introduction to the chapter

> Those who conduct research belong to a community of scholars, each of whom has journeyed into the unknown to bring back an insight, a truth; a point of light, what they have recorded of their journeys and findings will make it easier for you to explore the unknown… (Leedy & Ormrod, 2005: 64).

This chapter introduces the thesis. In addition to the context of the study, the chapter also reflects on national and international challenges faced by Science learners in mechanics, both first and second language speakers.

Most stakeholders, especially parents still view English as a superior language. There is a tendency of equating fluency in English speaking to success in school. Whilst one cannot underestimate the advantage of fluency in English in learning and teaching Science, I argue that it cannot be the only contributing factor to success in school Science.

Most schools in South Africa use English as their official language of teaching and learning, even though it is not the language spoken at home by the vast majority of learners. This causes practical tension for Science educators between communicating content in the language mostly understood by the learners and an obligation to use the official language of instruction (Probyn, 2004).

Furthermore, educators ought to teach learners Science language and how to use symbols because many may be failing Science as a result of language rather than the calculations or Mathematics involved. Lemke (1993) argued that symbols and signs are another form of literacy to be learnt (multi-modal).

The South African Concise Oxford English Dictionary (2001), describes language as the method of human communication, either spoken or written, consisting of the use of words in a structured and conventional way, any method of expression or communication. It further elaborates that language is also a system of communication used by a particular community or country, computing a system of symbols and rules for writing programmes or algorithms, manner or style of a piece of writing or speech.

However, from another perspective the language of Science does not always tally with the common English language, for example words like velocity, speed, acceleration and cell just to name a few, which have special meanings in Science. In line with Donovan (1978), I have observed that most learners both second and first language speakers have problems with the word ‘cell’ for it has three meanings, for example in street (everyday) language a cell means a small prisoner’s room, whereas in Biology it means a smallest unit of life and in Physical Science it means the small source of electrical energy (battery). This is one of the challenges in Science education in South Africa. The multiple use of one word causes practical tensions for Science educators between communicating content in the language mostly understood by the learners and their obligation to stick to the official language of instruction.

On the other hand, Probyn (2004) found that actual practice differed greatly. She argues that a different approach to teaching is required for second language learners, from the learner-centred approach, which is commonly advocated. Probyn *(ibid)* argued that where educators and learners share common home language, educators tend to switch to the learners’ home language – a practice known as code-switching. This is a school of thought, which is also echoed by Setati, Adler, Reed & Bapoo (2002). However, Wong-Fillmore (1985) warned that code switching might short-circuit learners trying to learn the foreign language.

Gibbons (1991) argued that many educators comment on how quickly children with limited or no English learn to communicate with their peers in the playground. However, playground language is very different from the language that educators use in the classroom, and from the language that we expect children to learn to use. Language of the playground is not the language associated with learning in Mathematics, Social Sciences, or Science. For example, the playground does not normally offer children the opportunity to use mathematical language like: increase the angle by five degrees, cut the circumference into equal parts (Gibbons, 1991). It is due to the above-mentioned reasons that language acts as a barrier in Science and Mathematics teaching and learning.

1.2 Background of the research study

The way learners are introduced to mechanics in schools may not promote the understanding of the concepts. Definitions are sometimes in conflict with linguistic reasoning and real life situations are seldom given. In this research study, the understanding of the scientific terminology will lead to the understanding or grasping of concepts is the primary concern starting with the learners' perspective on the 'experts' point of view. In everyday language the word acceleration means the rate of increase of speed, misunderstandings can therefore arise from confusion between the scientific and the common meanings (Warren, 1984). Yet in Science, acceleration means the rate of increase or decrease of velocity. There is almost universal agreement amongst Science educators and authors that the name should be given to this vector and that speed should be used for the rate of change of the distance travelled. Consequently, a very large proportion of learners will classify velocity and speed in task, unfortunately the nature of the distinction is not always clearly understood.

Furthermore, Warren (1984) argued that 'displacement' is very rarely discussed in elementary work, and velocity is usually described as speed in a particular direction. (One elementary book explains that a train travelling on a straight track has speed whereas one on a curved track has velocity!). Very often the word 'velocity' is used where 'speed' would be more accurate, as, for example, in reference to the 'velocity' of light or sound, or the muzzle 'velocity' of a gun. In innumerable problems numerical values are given for 'velocities' without any reference to direction. I therefore argue in light of this confusion, that it cannot be expected, in the circumstances, that learners will attach any real importance to a distinction that is made when the subject is first introduced and then ignored.

In line with Donovan (1978) who argued that the term 'Science' embraces a very wide area of subject matter, different learners will have widely differing interest with many sub-divisions. Donovan also argued that Mathematics forms a basic element in most scientific studies, and learners of Science need to be able to deal with numbers, operations and mathematical formulae. Donovan *(ibid),* further argues that this may involve the learner in understanding and producing spoken English, forms of equations, numbers, abbreviations and symbols, although the skill is not taught in English courses for foreigners.

Furthermore Donovan (*ibid)* argued that being taught Science in a foreign language presents a problem when preparing learners for the language they will need to study different branches of Science. It is therefore necessary to establish some common element in the language used in Physics, Chemistry and Biology and their associated disciplines. I tend to believe that learners should be able to define a word from the context or learning area it is used.

1.3 Context of the Research

In virtually every subject area, our knowledge is incomplete and the problems are waiting to be solved. We can address the holes in our knowledge and these unsolved problems by asking relevant questions and seeking answer through systematic research (Leedy & Ormrod, 2005:1).

This research study was conducted in my school in Ixopo, KwaZulu- Natal, where I have been teaching for the past three years. A teaching and learning unit of work in Grade 10 mechanics was designed and implemented although, not fully discussed in this research project. A post task was given to all the learners in Grade 10 Science class after the learning and teaching of this unit. The learners' Grade 9 final examination marks served as a pre-test in this research study.

I chose mechanics because I wanted to explore the challenges faced by the Grade 10 learners in making sense of the topic.

Barnes (1992) argued that new learning depends crucially on what the learner already knows. When we are told something we can only make sense of it in terms of our existing skills, for example, a child who has had no experience of blowing up balloons or pumping up bicycle tyres will make less sense of a lesson on air pressure than a child who had had such an experience. Also, in most cases some learners do not relate these experiences to the Science taught in the Science classroom. Yet retrieving and transforming what we already know is the crucial part of learning (Barnes *ibid*).

It was Piaget (1968), who pointed out that some knowledge and experience cannot be assimilated for understanding the world, and other new ideas because they do not fit, hence compelling us to accommodate them by changing our schemes. Acquiring new ideas requires a radical revision and this we sometimes resist.

On the other end of the spectrum, whatever teaching method an educator chooses – question and answer, guided discovery, demonstration or practical work – it will always be the learners who have to do the learning. Learners will construct their own meaning of the lessons only by using the new ideas or, experience, or ways of thinking in order to review their existing pictures of the world.

Educators should therefore strive to take into account the learners' prior knowledge and allow learners to bring out their ideas before teaching them, thus giving them an opportunity to restructure their ideas and develop the lesson from there. Most educationists generally believe that teaching is a journey from the existing (prior) knowledge to the unknown (constructed) knowledge.

Similarly, Ausabel (1980) stated that the most important single factor influencing learning is what the learner already knows, we need to ascertain this and to teach him/her accordingly. However, incorporation of such prior knowledge is usually a great challenge to most educators.

Furthermore, Backhouse, Haggarty, Pirie & Stratton (1992) also argued that failure to understand the meaning of words or symbols inevitably impairs communication. They further suggested that as Science educators we should be careful not only with technical vocabulary (language) but with words that we may regard as familiar that may be difficult for learners. Backhouse *et al.* (*ibid)*, suggested that special meanings in Mathematics / Science need to be pointed out at the first opportunity and reminders will probably be needed from time to time.

Furthermore, Vygotsky (1978) also examined the importance of language. He further argued that classrooms would be very strange places without use of verbal communication (spoken/written words) and non-verbal communication (graphics, drawings, pictures, signs and symbols as the vehicle of information).

For instance, I usually code-switch a lot in the junior classes compared to the senior classes (using English to teach and Zulu to facilitate understanding), despite the fact that the medium of instruction in my school is English first language. My reasons for doing this include my having observed that most learners, if I insist that learners should use English during Science lessons, withdraw from participating, but if allowed to ask and express their views in their mother tongue (Zulu), there is a lot of participation, especially in the junior classes. I am tempted to say that they know the answers and have questions on the work at hand but they cannot express themselves in English. The English language proficiency of the majority of learners frequently does not meet the demands of learning through the medium of English (Probyn, 2004).

Wong- Fillmore (1985) suggested that it is possible to accomplish both goals – language and content at the same time but doing so requires that the competition between these two sets of instructional objectives be recognised and resolved. Educators need to code-switch in order for learners to understand the content, thus by doing so these two sets of instructional objectives will be reconciled. However, Wong-Fillmore (1985) warned that code-switching could short circuit the instructional language by making learners not to see the need to learn the second language English. The problem with code-switching is that although the learners may understand concepts in Zulu, they may fail the examinations as they are written in English (See 1.1 page 2).

Orr & Schutte (1992) note that readers in an academic environment often feel overwhelmed and intimidated by the complexity of the texts with which they have to deal with in Science courses. They argue further that English classes at school seldom equip readers with the unique reading skills that the Sciences demand and few are fluent in the unique languages of the Sciences (or indeed, even aware that such special 'language' exists). These difficulties are compounded for those for whom English is not a first language. They point out that the language of Science arose out of desire to meet the needs of learners, scientists and lecturers (in English or in Science) facing this challenge.

Furthermore, Orr & Schuttle (*ibid)* cited that learners and practitioners of any Science find that the language skills differ from content of conversational language classes, in that they focus specifically on English used in Science. The assumption here is that Science language skills could enhance conceptual understanding

As Kilpatrick, Swafford & Findell (2001) claimed that conceptual understanding refers to an integrated and functional grasp. Learners are thus able to organise their knowledge into a coherent whole, which enables them to learn new ideas by connecting those ideas to what they already know. Conceptual understanding also supports retention. That is, facts and methods learned with understanding are connected, they are easy to remember and use, and they can be reconstructed when forgotten.

In line with Orr & Schutte (1992), Barnes (1992) argued that learning is seldom as simple as a matter of adding bits of information to existing store of knowledge though some adults have received this idea of learning from their own schooling. Most of our important learning in school or out is a matter of constructing models of the world, finding how far they work by using them and then reshaping them in the light of what happens.

Experience, however, has also taught me that a chapter like vectors and scalars, which includes mechanics (which is a focus of my study), always presents a challenge to the learners, because of its mathematical nature. This proves that mathematical proficiency (in addition to language) is essential in learning and teaching Physical Science. Furthermore, Setati, Adler, Reed & Bapoo (2002) in line with Donovan (1978) stated that there is a significant relationship between language and learning and between proficiency in the language of instructions and success at school.

In line with Setati *et al.,* (*ibid*), Farrad & Lee (1999) argued that language proficiency and literacy are closely related to Science learning. They argued further that learners with little Science knowledge and vocabulary produced a least amount of language and were least aware of how to use cognitive strategies. Learners with moderate Science knowledge and vocabulary frequently produced the largest amount of language, often talking in circular and repetitive ways. These learners frequently use a variety of Science strategies. Learners with comprehensive Science knowledge and vocabulary often used a moderate amount of language, spoke precisely using specific vocabulary and used strategies related to the task.

Furthermore, O'Brien & Scott (1996) proposed to encourage foreign language educators to foster an attitude to writing, in learners, which enables them to see not as grammar, not as creative writing; but as a discovery of meaning. I fully agree with O'Brien & Scott *(ibid)*, since our colleges of education and universities up to now do not 'train' educators how to teach English to foreign language speakers. In many schools, in South Africa the majority of English educators are second or third English language speakers who are also struggling to a certain extent since they are using a foreign language. The second language learners battle not only with English language but with the subject-content as well.

On the other hand, Stepels & Haselden (2002) believed that Science has a literacy of its own which is separate from core literacy shared by all subjects. Thus Science educators have a responsibility to develop this literacy in their learners, enabling them both to access the Science curriculum and explore standard methods of communication within the subject. I have also observed from practical experience that there are thin lines between listening, speaking, reading, and writing Science language, these are in my view like a spider's web.

The main goal of this research study was to investigate the challenges facing Grade 10 learners in sense-making of mechanics problems. By challenges I refer to the things that might not help or hinder learners from understanding mechanics problems.

To achieve this research goal, I:

- Compiled a task in mechanics.
- Gave the task to my critical friend before giving it to my Grade 10 learners.
- Marked the task and then interviewed learners in order to analyse their responses to illustrate meaning-making.
- Gave the marked task to my critical friend and then interviewed him.

Research questions were formulated with the view to illuminate learners' sense-making when faced with problems in mechanics:

- What are some of the challenges facing Grade 10 learners in sense-making in mechanics word problems?
- Do learners' justifications of their responses in a mechanics task help to illuminate their challenges?

Furthermore, I believe that writing is the way of expressing our thoughts, which are, directly or indirectly determined by what we have read, spoken about or listened to, from a given environment. In view of these arguments, it is recognized that the significance of this study will be to:

- Provide opportunities for practicing Science educators an understanding of some of the challenges faced by learners in learning mechanics.
- Improve Science teaching and learning in general and in particular at Ixopo High School where I currently teach Physical Science from Grade 10 to Grade 12.

1.4 An overview of the chapters

Chapter one introduces the study by discussing the overview, the context and the background of the study.

Chapter two focuses on literature review in which educational theories are discussed analysed and critiqued.

Chapter three seeks to describe the research processes and the methodology employed in the research

Chapter four is devoted to the results of the research.

Chapter five is mainly focused on the data analysis and findings of the study

Chapter six aims at discussions, recommendations and conclusions

Chapter seven explores significance of the study, potential areas for future research, limitations of the study and reflections.

1.5 Conclusion

In this chapter, the following aspects of the research project have been looked into: background to the research study, the context of the study and the overview of the research chapters. Furthermore, the chapter explored some of the views of both national and international researchers in as far as the challenges faced by the science learners during the teaching and learning process. In the next chapter, a detailed discussion of the literature review will be provided.

Chapter two

Literature review

The importance of language in learning and teaching Science cannot be under-estimated. It is important for learners in developing their scientific knowledge, and for educators in understanding their learners' learning processes. But research has shown that the ways in which educators use language in the classroom and learners are complex and the effects, though considerable, are often highly subtle and not self-evident. Therefore it is important to develop what happens with language, why it happens and how it happens, since language is a tool that is used for expressing information and ideas. A variety of linguistic and non-linguistic modes are used for communication: listening and talking; reading and writing; discussing and arguing; narrating and describing; using actions, images and symbols – all of which are ways of signalling meaning and what linguistics term 'semiotics' (Lemke, 1998).

2.1 Introduction to the chapter

This chapter explores the many multi-faceted nature of language within the context of teaching and learning Science in the classroom. This discussion will be followed by brief examination of interdisciplinary and co-operative effort between language teaching and Science. Throughout the chapter efforts have been attempted to explore ways of tackling the reading of Science textbooks and some elementary strategies for managing and manipulating Science information. It does so in the following subsections: conceptual understanding, learning theories, constructivism, good practice in Science teaching, the classroom as a site of multiple discourses, talking Science and problem solving in Science.

I focused my literature review on challenges in mechanics and also drew from my experience as a Science practitioner.

2.2 Some common problem areas in Grade 10 mechanics

I have come to realise that most learners in my school battle to make sense of word problems in mechanics. They also seem to struggle with the construction of drawings from the given word problems. As a result, they struggle with the chapter on *vector*s and *scalars*, which includes mechanics. It is for these reasons that Macdonald (2001) suggested that educators need to know how learners learn and why they struggle to learn what they have been taught.

Experience has taught me that most learners can deal with the mathematical equations of Science without necessarily understanding the meaning of the equation. Skemp (1996:20 - 26) pointed out that "instrumental understanding" is learning rules without reasons in contrast with the "relational understanding", that is, knowing both what to do and why.

Some research studies in mechanics (Warren, 1984; Galili, 1995; Dekker, 1997; and Taska, Monroy & Sassi 2000) revealed that most learners are fairly well able to select the right formulae and laws and apply them correctly in answering quantitative questions. It seemed however, that they understood neither the concepts involved, nor relationship expressed in the laws. These researchers are inclined to believe that they tasked only learners' ability to slot numbers into rote-learned formulae that for them are meaningless. Yet, Kilpatric, Swafford & Findell (2001) believed that learners with conceptual understanding knew more than isolated facts and methods.

Also, Skemp (1976) argued that the symbolic aspect of written Science is one of the subject's most apparent and distinctive features that plays an important role in word problems, for example $\approx, \equiv, \leq, \geq$ and so on. Pimm (1981) posted that symbols perform a variety of functions in our everyday lives and in the context of Science. I would suggest that Science educators should teach learners symbols as I believe that they form an important part of the Science register.

It should also be recognised that the seemingly scientific language used in everyday life might be at odds with the language of school Science. This could also cause difficulties for dealing with word problems.

Furthermore, Macdonald (2001) suggested that we should be careful in our use of not only technical vocabulary (language) but concepts that we may regard as familiar to us as Science specialists but may be difficult to learners. Heselden & Staples (2002) echoed this view and believe that Science has a literacy (its own language, interpretation, meaning) of its own which is separate from core literacy (everyday language) shared by all subjects.

2.3 Conceptual understanding

Mathematical proficiency as viewed by Kilpatric, Swafford & Findell (2001) has five components or strands namely:

- Conceptual understanding – comprehension of mathematical concepts and relations.
- Procedural fluency – skill in carrying out procedures flexibly, accurately, efficiently and appropriately.
- Strategic competency – ability to formulate, represent and solve mathematical problems
- Adaptive reasoning – Capacity for logical thought, reflection, explanation and justification.
- Productive disposition – habitual inclination to see Mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy.

To echo the above components or strands, I once gave a density exercise to a class of Grade 10s. They were calculating density from its formula (D= m/v) of which the majority (98%) got the answers. When I asked them at the end of the lesson what they had understood by the term density, some thought it was how light or heavy an object is and some associated density with mass or volume of an object and some had no clue of what density is. These learners could not make sense of the activity, or rather could not understand why numbers were manipulated to get to an answer. Learners lost sight of the importance of the answers, use of answers in the context and organisation of knowledge into a coherent whole as suggested by Schoenfeld (1985) and Warren (1984).

Orr & Schutte (1992) argued in support of Schoenfeld (1985) that readers in an academic environment often feel overwhelmed and intimidated by the complexity of the texts, which they have to deal with in Science courses. They argued further that English classes at school seldom equipped readers with unique reading skills that Sciences demand and few are fluent in the unique languages of the Sciences (or indeed, even aware that such special ‘language’ exists). These difficulties are compounded for those whom English is not a first language. They pointed out that the language of Science arose out of desire to meet the needs of learners, scientists and lecturers (in English or in Science) facing this challenge. They also cited that learners and practitioners of any Science find that the scientific language skills differ from content of conversational language classes, in that they focus specifically on English used in Science.

Furthermore, Orr & Schutte (*ibid),* proposed that learners and practitioners should not always try to learn and teach Science through examples and problems such as in the mechanics task, but focus on the language, conventions and underlying structure. I think that this is important because apart from the subject-content, Science educators should take time and teach the scientific terminology to their learners.

On one hand, Mathematics forms a basic common element in most scientific study, and learners of Science need to be able to deal with numbers, operations, and mathematical formulae. Donovan (1978) argued further that this may involve the learner in understanding and producing the spoken English, forms of equations, numbers, abbreviations and symbols, although this skill is not taught in English courses for foreigners.

Similarly, Pimm (1997) argued that Mathematics is not a natural language in the sense that French and Arabic are. For instance, there is no group of people for whom Mathematics is their first language. Pimm *(ibid)* further argued that Mathematics is not even a “dialect” of English (or any other language which can be used for mathematical purposes). I believe questions in Science do not assess scientific knowledge only, but an acquaintance with the subject. Pimm *(ibid)* also suggested that one use of written language is to externalise thought in as stable and permanent form, so the writer may reflect it upon, as well as providing access to others. I think as a result of more language being used other than the scientific/mathematical knowledge involved, most learners attain less in Science.

On the other hand, Van Heuvelen (1991) argued that learners of Physics tend to be passive observers while educators tend to demonstrate the algebraic aspects of solving problems. He further suggested that learners could learn to think like physicists when given opportunities to reason qualitatively and make use of translations from verbal, pictorial, and Physics representations, before switching to the mathematical form of physics problems.

Similarly, this school of thought is also shared by Redish (1994) who argued that learners should be given opportunities to do qualitative reasoning, to construct mental models, and learn to apply their modes.

On the contrary, Wong-Fillmore (1985) argued that educators have a curriculum to teach over the course of the year. In order to cover the curriculum in that time, they have to exercise control over the social behaviour of learners in class. The aspects of this control involve the scheduling of events and organisation of lessons. She further argued that behaviour is controlled during instructional event thus educators regulate the topics of discussion, its pacing and its direction. The educators also decide who gets to talk and for how long and finally they judge what learners have to say, how they say it and correct them when it is deemed necessary.

2.4 Learning Theories

Different learners have different learning styles and it is important for educators to acknowledge and accommodate learners as different individuals as reflected in the multiple intelligence theory by Gardner (1999). Multiple intelligence theory is important in teaching and learning because every learner is different and should be treated differently. Thus, flexible time frames allow learners to work at their own pace as advocated by the outcomes-based education.

Furthermore, Macdonald (2001) claimed that educators, more especially Science educators, should address the following questions to understand what is involved in learning:

- How do learners learn?
- Why do learners struggle to learn what they are taught?
- Why do learners forget what they have been taught?
- When are learners successful in learning?

I fully agree with Macdonald (*ibid)* because I believe the answers to those questions should go a long way to understanding some of the challenges faced by learners in the mechanics lessons. Macdonald *(ibid),* further viewed constructivism as common to the works of both Piaget and Vygotsky and suggested that this could be the best angle to start helping learners in trying to do problems in mechanics with understanding. Macdonald claimed that constructivism seems to hold promise for explaining how we learn.

Furthermore, Macdonald *(ibid),* argued that constructivism can be contrasted with a philosophy of knowledge called realism, which holds more different intuitive views about our relationship with the world. She defined realism, as a view that there is a real world out there and the tasks of Science are to discover these 'realities'. According to Macdonald, educators are teaching learners facts about the real world and learners should simply learn these (jug and mug approach). She also pointed out that from a view based on realism; we need a God's eye-view of things. We cannot by definition have a God's eye-view of things (even though sometimes educators believe they do)! She suggests that the educator can only present his or her views, which could be very different from those of the learner. In line with Macdonald *(ibid)*; Backhouse *et al.* (1992) I use many applications and practical examples with my lower classes so as to connect Science to the real world.

2.4.1 Constructivism

Educators are often wary of theory – they want something practical, yet in the end there is nothing as practical as a good theory. Theory is like a lens through which one views the facts; it influences what one sees and what one does not see (Olivier, 1989). The theory underpinning this research study is constructivism. The definition of constructivism is carried in its name. Learning is the active process of constructing or putting together a conceptual framework (Cobern, 1995).

A constructivist perspective on learning (Piaget, 1970; Skemp, 1979) assumes that concepts are not taken directly from experience, but that a person's ability to learn from and what he learns from experience depends on the quality of ideas that he is able to bring to that experience.

Furthermore, from the constructivists' point of view, knowledge does not simply arise from experience. Rather, it arises from the interaction between experience and our current knowledge structures. Thus, the learner is therefore not seen as passively receiving knowledge from the environment; it is not possible that all knowledge can be transferred ready-made and be passed from one person to another.

Similarly, Roschelle (1997) in arguing for the importance of the prior knowledge stated that research has shown that learners' prior knowledge often confounded an educator's best efforts to deliver ideas accurately. A large body of findings shows that learning proceeds primarily from prior knowledge and only secondarily from the presented materials (Cobern, 1995; Roschelle, 1997 and Macdonald, 2002). Prior knowledge can be at odds with the presented material and consequently, learners will distort presented material. Neglect of prior knowledge can result in the audience learning something opposed to the educator's intentions, no matter how well those intentions are executed in an exhibit, book or lecture.

Similarly, in arguing for constructivism, Macdonald (2001) suggested the following:

- It starts where the learner is. She suggested that this is taking advantage of a child to further his or her understanding. She argued that this is not a common scenario for secondary subject specialists whose life is often governed by the condition of whole ground classes, not individuals. In her opinion, the learning starting point is commonly some national ‘norm’ of class achievement, seldom the conceptual state of the individual.

- ‘Linear progression’ through orientation, elicitation, restructuring, application and review. She suggested that the learning environment must be structured in such a way to encourage the explication of ideas and provide challenging experiences.
- Designing bridges, ‘stepping stones’ or immediate steps to take a learner to the desired point. She pointed out that this consists of two points, the strength of supporting evidences being provided and the timeliness of the interim ideas.
- Furthermore, she argued that the task of the educator is to know the learners sufficiently so that the instructional step is strong enough both to help to transport ideas for particular individuals and be sufficiently frequent along the bank of experience. According to her, this allows the river of the knowledge to be safely crossed, as suggested by the curriculum document. The curriculum in practice helps learners to reach the end of the journey assuredly.
- ‘Forms of active learning’: ‘learning is not just listening and writing’. Macdonald viewed this as an antidote to the ‘blank slates’ view of learning. She also suggested that group work, collaborative learning, and peer group learning as examples to encourage learners to understand phenomena.
- ‘Educators/facilitators/enablers. She further argued that since classroom management is important, educators must design organised situations in which ideas can be discussed without fear of ridicule. In this process educators encourage learners to explore ideas themselves, rather than being directive in their suggestions.

The primary task of the educators is not to teach but to ensure that the learners learn (Dobson, 1986). This was echoed by Farmer & Farrel (1972), who suggested that we should start by saying that the great task of any educator and this includes Science educators, is tackling the mismatches that occur between what is taught and what the learner learns.

Furthermore, Farmer & Farrel (*ibid*) suggested that learners' processes (learners making their own understanding) would be greatly simplified if Science educators could confidently declare that the learners have taken aboard what they have been asked to learn. They further suggested that as educators we must not only know how best to teach, but must be aware of the current theories most importantly how best learners learn. Finally, they pointed out that educators should realise that if it is their objective to present an excellent lesson, this could be achieved even in an empty classroom. The guided question as advocated by other educationalists is: are educators teaching learners content or teaching content to learners? They further suggested that learners are the ones who are being taught and there should be more emphasis on them rather than content.

Similarly, Fairbrother (1995: 13) argued that learners should regulate their own learning, which in his words "the activities are as important in Science as in any other subject". He suggested that such self-regulation involves overlapping learning strategies.

- Cognitive – the learning of the content of the subject (for example, electric charge, homeostasis), where learners select information from what is presented to them (notes copied from the board, the results of an experiment and so on). They then have to elaborate and organise the information to add coherence and integrate new information with existing knowledge and use various revision strategies.
- Meta-cognitive – a process of learning whereby learners use a variety of planning, regulating and evaluating strategies and think about what they are doing when they are learning.
- Motivational – which involves learning for its sake, a belief in the value of the task and a belief in one's own abilities, i.e. self-efficacy? Fairbrother *(ibid),* further argued that learning strategies are not necessarily the same as teaching strategies that educators use, although there can be some overlap. He advocated that the overlap occurs when good learners themselves can use teaching strategies; two examples are concept mapping, which is largely a

cognitive strategy because it involves an understanding of scientific concepts and the relationship between them.

According to Fairbrother (1995), all learning strategies require that learners be made explicitly aware that what they are doing can become a part of their own learning armoury. He believes that educators and learners need to know a range of learning strategies because learning different strategies will suit different learners, variety in learning is as important as variety in teaching. Fairbrother *(ibid)*, drawn from Bergin (1996), found that high school learners used very few learning strategies out of school which indicates that there is a need for more school instruction in learning strategies that encourages their transfer out of school. Fairbrother *(ibid),* found that educators needed training, administrative support and peer encouragement in order to teach and apply different learning styles and teaching strategies.

Furthermore, Backhouse *et al*., (1992) argued that failure to understand the meaning of words or symbols inevitably impairs communication. They further argued that as Science educators we should be careful not only with technical vocabulary (language) but with words that we may regard as familiar that may be difficult to learners. Moschkovik (1996) stated that there are multiple meanings for scientific terms within the Science register (terminology) in each language; one scientific term in Spanish may have several English terms associated with it. I used different strategies with different classes: the Grade 10s are not yet familiar with many concepts and the Science register. My experience reveals that an educator has to market Science by teaching learners the Science register, which in most cases is different from the everyday English language.

However, experience has taught me that most learners can deal with the mathematical part of Science without understanding the meaning of the equation. For instance, my class got all the answers correct when manipulating the formula for density, without knowing why they were correct. They simply employed the prescribed methods without understanding:

$$Density = \frac{mass}{volume}$$

These learners lacked sufficient mathematical knowledge acquainted with Science language. I also took time to teach my lower classes the use of symbols and numbers. Symbols are a language on their own. I think that Science educators should teach learners symbols because I believe that they form an important part of the Science register. This is in line with Pimm (1981) who suggested the symbolic aspects of written Mathematics are one of the subject's most apparent and distinctive features. Pimm *(ibid)* argues further that symbols perform a variety of functions in our culture and in the context of Science and Mathematics. I believe Science ought to give learners a good Science language and should teach them to use symbols because many learners fail Science as a result of a language and symbols used than the calculations or Mathematics involved.

On the other hand, I also think that educators need to realise that Science goes beyond the walls of the classroom/laboratory. I also consider learners' developmental stages suggested by Piaget (1968). The concrete stage (7 –12 years) should be treated differently to the formal stage (12 – 16 years). Ausabel (1985) stated that one of the factors influencing learning is what the learner already knows, ascertain this and teach him/her accordingly. However incorporation of such prior knowledge is usually a great challenge to most educators. Educators should take into account the learners' prior knowledge and allow learners to bring out their ideas before teaching them. Thus giving them an opportunity to restructure their ideas and develop the lesson from there. Most educationalists (Ausabel, 1985; Piaget, 1968 & Roschelle, 1997) generally believe that teaching is a journey from the existing (prior) knowledge to the unknown (constructed) knowledge.

As mentioned above, I employed different teaching styles to suit different learning styles that learners may have. For instance, in all junior classes I allow a great deal of group discussion. A group discussion between learners about understanding is largely meta-cognitive because it involves not just what learners understand but how they gain that understanding. During group discussions there should be a system of inter- individual relations. The individual develops a social point of view, distinguishing his/her own from those of others, discussing and participating in co-operative acts, at the same time as he/she develops operational thinking (Macdonald, 2001).

However, Macdonald (2001) pointed out that one is bound to accept the position or conclusion of other peers especially if one has participated in the discussions. While on the other hand with peers they are free to negotiate their position, and so the learners' concept is more fully developed. That is, learning is a social activity (small group learning especially with peers facilitate understanding). This mostly allows learner-learner interaction as opposed to educator – learner interaction. I also think this gives a lion's share of the lesson to the learners.

Furthermore, Vygotsky (1978) argued that the use of language is indispensable in classrooms. Vygotsky *(ibid)* further argued that classrooms will be very strange places without the use of verbal communication (spoken/written words) and non-verbal communication (graphics, drawings, pictures, signs and symbols as the vehicle of information). Thus, language permits educators to move from group to group *scaffolding* where necessary. It also gives a chance to the gifted learners to help the less gifted. I think it is important for the educator to check on the seating arrangement of learners: all groups should be composed of mixed abilities, thus giving a chance to the gifted learners to help the less gifted.

Thus, it is the duty of each educator to create a constructive learning environment, where learners will feel safe to make individual statements (which contradict that of an educator) and an educator has to feel confident enough to allow a learner to explain further what may seem to be an odd perception as suggested by Macdonald (2001). It is also important for us as Science educators to realise that learners are not empty vessels and also that we, educators are teaching learners.

2.5 'Good' Practice in Science Teaching

Jones (2000) argued that the importance of language in the learning and teaching of Science should not be underestimated since it is important for learners in developing their scientific knowledge and for educators in understanding their learners' learning process. Jones, *(ibid)* further argued that language is a tool that is used for expressing information and ideas. According to Jones, a variety of linguists and non-linguistic modes are used for communication. Listening and talking, reading and writing; discussing and arguing; narrating and describing, using images and symbols all of which are ways of signalling meaning and what linguistic term 'semiotic'. How we communicate depends on a range of contextual factors such as the situation, the resources of the participants and the interaction between them, the topic and the purpose of communication.

Furthermore, Lemke (1997) argued that scientists attempt to communicate by using highly specialised language – the language of Science. The Science language incorporates more than just words; scientists draw on a multitude of signs and symbols (a multi –semiotic system) to communicate their ideas. These signs and symbols include graphs, charts, diagrams, mathematical signs and equations as well as natural language. Therefore Science educators need to develop scientific knowledge and understanding and learners also need to develop the ability to communicate and use the discourse of Science in classroom to optimise their learning. The major problem is that some educators are Second Language English speakers. Therefore educators need to develop a critical and sensitive awareness to how language works in the classroom. This awareness needs to take account of the constant dynamic interaction between language and thought. This is crucial to developing learners' ideas and interpreting their beliefs; inevitably, problems arise through miscommunication and need to be anticipated.

Jones (2000) explored the multifaceted nature of language with the context of teaching and learning Science in the classroom under the following sections:

- The classroom as a site of multiple discourses.
- Talking past each other.
- The nature of Science discourse.
- Talking Science.
- Reading Science.
- Writing Science.
- Investigating Science by exploring language.

Each section attempts to illustrate the importance for the educators of attending to language and the importance of language for learning Science.

2.5.1 The classroom as a site of multiple discourses

Learners bring into the Science classroom a great variety of common sense or views derived from individual experiences of the world. They also bring their own linguistic resources and communicate repertoires developed from early childhood in a variety of social settings. These contribute to the social context of the classroom (Lemke, 1990) where the learners' own discourse gradually becomes extended to incorporate scientific discourse. Scientific discourse comes about through a complex process of socialisation that involves code-switching, using language for different purpose with different social determinants for what may, and may not, be said developing a sharing of experiences and thereby leading to the development of scientific knowledge and understanding. Most children quickly become adept at code-switching in situations they encounter, although it seems that middle class children are much better prepared to develop a formal use of language than are working class children (Barnes, 1992; Lemke, 1997).

In addition, it is not easy to determine whether code-switching takes place within the classroom or not. Frequent shifts between talking about individual feelings or problems, describing and discussing scientific content, and the language of classroom management are just a few that occur. In a multi-lingual classroom language issues are complicated further. Using English as additional language (EAL), learners may have developed sophisticated strategies for coping with the varieties of English they encounter. For them, scientific language may be yet another type of experience (Rosenthal, 1995 as cited in Jones, 1997). Their code switching is an additional layer to using different languages. Within the classroom, the Science educator's way of talking interacts with those of their learners to channel and develop the ability to engage in and share scientific discourse.

I code-switch a lot in the junior classes compared to the senior classes. I believe in code switching, I market Science to most of the second or third language English speakers. Although the medium of instruction in our school is English first language, I observed that most learners, if I insist that they should use English during Science lessons, most learners withdraw from participating, but if allowed to ask and express their views in their mother tongue (isiZulu), there is a lot of participation by most learners, especially in the junior classes. I am tempted to say that they know the answers or have questions on the work at hand but they cannot express themselves in English.

Furthermore, the English language proficiency of the majority of learners frequently does not meet the demands of learning through the medium of English. As a result, where educators and learners share a common home language, educators tend to switch to the learners' home language – practice known as code-switching (Probyn, 2002). Wong – Fillmore (1986) as cited by Probyn *(ibid),* suggested that it is possible to accomplish both goals, namely: code-switching and English at the same time but to do so requires that the competition between these two sets of instructional objectives be recognised and resolved.

Furthermore, Gibbons (1991) suggested that using the mother tongue for learning allows children to draw on their total language experience and so continue their conceptual development. Gibbons *(ibid)* further suggested that ignoring children's first language is wasteful, because it ignores one of the greatest resources they bring to school. However, ultimately, I still found my learners having difficulty in grasping mechanic concepts.

2.5.2 The nature of the scientific discourse.

The language of Science is a purpose designed tool to be used in specific contexts to meet specific needs (O'Toole, 1996 and Veel, 1998) argued that like all languages, Science is a dynamic language and as new meaning emerges. Veel *(ibid)* cited three influences that explain why scientific discourse continually expands and changes.

Firstly, there is the emergence of new fields of scientific activities as with the field of genetics last century. Either previously established knowledge is challenged or new concepts and ideas are constructed.

Secondly, new sets of social relations emerge for the users of scientific discourse, requiring the language to be modified for different audiences, which in its turn, influences the language of Science.

Finally, there is influence of new modes of representing and reproducing knowledge. Such tools have transformed a large number of scientific enterprises, from epidemiology to nuclear Physics (Jones, 1997).

2.5.3 Talking Science

In the classroom, Science is reconstructed for the learner through a variety of linguistics interactions (Christie, 1998), and sometimes the views that learners bring from their own communities are not given enough attention and respect. I think this is because the Science syllabus is still exam driven and the educators race to finish the syllabus, thus shutting out what the learners bring from their communities. Due to this rush, learners are denied an opportunity to express their prior knowledge. Educators have no idea of what misconceptions learners may have and there is nothing to restructure, hence learners remain in the same position.

2.5.4 Talking past each other

There is a considerable gap that exists between the learners' world and the world of the Science they are meant to learn about (Lemke, 1990). Consequently too often, there is a breakdown in communication in the classroom, which leads to considerable frustration. Science discourse, as Lemke *(ibid)* explained, can privilege the expert and alienate learners, thus nurturing in the latter a certain harmful mystique of Science, where a learner's intelligence abilities and motivation are undermined.

He further argued that Science is often presented as being difficult in the classroom because it is perceived as having certain authority to state absolute facts and objective 'truths'. This is achieved through the use of languages that highlight objectivity, in preference to subjectivity of experience, thus generating a conflict between the specialised technical and scientific discourse of experts and common sense talk of people in general. Clearly, one of the main goals of Science education is to guard against such conflict and alienation. We need to find ways of expressing the excitement of Science without the frustration that is inherent in a new language, new ways of speaking or the consequent miss-negotiation of meaning.

2.5.5 Communication through more than words

Jones (2000) suggested that Science has to use a multi semiotic system to convey its meaning effectively for natural language is poor at representing the nature of the phenomena with which Science is concerned. Natural language is very good at conveying binary opposites for example black and white, but poor at conveying the many shades of grey that lie between them. The popular saying that a 'picture is worth a thousand words' particularly applies to communication of scientific ideas for instance consider one good diagram thus several modes of communication are needed to convey meaning in the Science classroom.

Visuals, graphic representation, mathematical equations, tables, charts, photograph actions and so on as well as nature of language (Halliday & Martin, 1993; Lemke, 1998) convey scientific meaning better. The scientific description of that word, no matter how complex the translation is in signs is taken one step further, thus diluting the Science that is taught. Halliday & Martin (1993) argued that rather than seeing words as having a fixed meaning, it is useful to think of language as having a meaning to contextual and that leaves room for the individual to interpret meaning with a context. Lemke (*ibid*) claimed that the process of individual reconstructions come naturally but he also emphasised that the learners' individuality interest the knowledge and the experience in this sense the text that is already established in their minds.

2.6 Investigating Science by exploring problem solving

"What I cannot create I cannot understand", Richard Fayman, as cited by Fortunato, (1991).

2.6.1 Problem Solving

Fortunato (1991) defined a problem as something difficult to deal with or understand or a means of posing a situation mathematically and then solving it. He further argued that each one of us has our own methods of solving problems, and this is important as it opens up awareness in order to help each other. Learning is a social activity. He also suggested that once a problem has been solved successfully, it ceases to be a problem. The learning can be used to solve similar or different problems in future. He illustrated problem solving with a young child learning to dress himself. He argued that in this case the child uses trial and error, tries different methods to find an answer and is frequently frustrated before a meaningful solution is found.

Furthermore, Fortunato (*ibid)* pointed out that even parents are also rejected when they try to help – the child wants to solve the problem his or her way and in this way the solution is meaningful to the child – it is his or her solution.

Similarly, Hobden (1999) argued that when addressing problem solving skills, one ought to look at what one means by 'problem'? He further argued that a task is problematic when:

- there is a situation that needs an answer
- the path to the solution is not apparent (we do know what to do).

In the light of this Hobden *(ibid)* further argued that for the task to become a problem-solving event, the learners must:

- Recognise that there is a problem

- Attempt and see that they are blocked getting to the answer
- Accept that they need to explore alternative paths or approaches.

In line with Fortunato (1991); Hobden (1999); Schoenfeld (1985) outlined a framework for examining what people know and what people do, as they work on problems with substantial mathematical content. Schoenfeld illustrated this by considering what happens when an individual or a small group of people works out aloud on a mathematical problem of moderate difficulty. He argued that the problem solver does not have easy access to a procedure for solving the problem.

This is a state of affairs that would make the task, an exercise rather than a problem. The problem solver does not have an adequate background with which to make progress on it, say it might be feasible to reach a solution in a half hour or so, and the individual or small group wants to solve the problem and works actively at it.

Furthermore, Schoenfeld (*ibid*) took for granted the need for one to ask the following questions if one is to observe and interview the problem solver:

- What is taking place during the solution attempt?
- What knowledge is accessible to the problem solver?
- How is this mathematical knowledge chosen?
- How is it used?
- Why does the solution evolve the way it does?
- In what ways do the approaches taken to solve the problem reflect the individual's problem-solving performance?
- Finally, what accounts for the success or failure of the problem solving attempt?

In line with Schoenfeld (1985) early in my career I took the ability to solve problems as an operational definition of understanding. I also thought one understands how to think mathematically, when one is resourceful, flexible and efficient in one ability to deal with new problems in Mathematics yet, examining the problem solving performance of most of my learners revealed some unpleasant realities. My experience gathered from observations of teaching mechanics confirmed that learners have little or no awareness, or ability to use, mathematical heuristic (allowing a person to discover or learn something for himself).

In line with Schoenfeld (1985), I came to realise that in some cases, learners survived often with good grades by implementing well-learned mechanical procedures, in domains in which they understood nothing about like in the case of density mentioned earlier in this research project. Another common meaning of problem solving emerges from its interpretation as a dynamic, ongoing process. In a recent issue of the arithmetic teacher devoted to problem solving, Krulik (1980:16) stated that "in problem solving an individually acquired set of processes is brought to bear on a situation that confronts the individual". The national council of teachers of Mathematics (1977) as cited by Krulik (1980:2) defined problem solving as "the process of applying previously acquired knowledge to a new and unfamiliar situation".

Similarly, Physics instructors and educators generally accept that problem solving leads to an understanding of Physics (Maloney, 1994 and Hobden, 1999). However, success in calculating correct numerical answers implies a corresponding level of conceptual understanding (McDermott, 1991). In fact instruction focusing on problem solving often ignore intellectual objectives and could encourage learners to concentrate on algorithms instead of Physics. Poor conceptual understanding has been demonstrated by various studies (Schaffer & McDermott, 1987; Pride, Vokos & McDermott 1998; Kim & Park 2002). These studies suggested that learners learn to solve standard problems in Physics without applying conceptual and interpretative knowledge.

Furthermore, Dhillon (1998) observed that novice problem solvers have difficulties to relate quantities, and use symbols to infer connections. On the contrary, the experts used conceptual meaning of quantities to relate to them. According to Maloney (1994) the most striking difference between the experts and the novices' approaches was found in the experts; application of general Physics which were for the most part not found in the novices' solutions. The novices typically used mean-end analyses, focusing on the gap between the required answer and the information, thus filling in steps to complete algebraic solution. Thus Hewitt (1983) proposed that conceptual reasoning should form part of examinations in order to encourage learners to understand concept..

McDermott (1991) also advocated that learners should be intellectually engaged in the learning process in order to bring about significant conceptual change. She further suggested that a deep mental engagement could be developed when the learners are required to explain their reasoning in their own words.

Similarly, Greeno (1989) argued that the issue of learners' problem solving without their understanding of the relation between algebraic solution and reality is described as 'insulation' of the symbolic world from the 'situated nature' of problems.

Furthermore, Greeno (*ibid*) proposed a model for scientific problem solving and reasoning that provided an explanation to this question. The model is based on four domains of knowledge namely:

- Concrete domain (Physical objects and events)
- Model domain (models of reality and abstraction)
- Abstract domain (concepts, laws and principles domain)
- Symbolic domain (language and algebra)

Symbolic model explains the possibility that algebraic solutions can become disconnected from concrete situation it represents. Greeno (*ibid*) in line with McDermott (1991) argued that in the classroom, learners manipulate symbols to solve problems, while the concrete problem situation is seldom present. This classroom reality can therefore lead to the belief that problems are about symbols, rather than about concrete situations represented by the symbols. Algebraic solutions, according to Greeno (*ibid)* can therefore amount to operations on knowledge located only in the domain of symbolic knowledge without translation to the concrete, model or abstract domains. Finally, Greeno (*ibid*) warned that such an approach can sometimes lead to correct equations and correct numerical answers, but does not demonstrate or develop an understanding of meaning of the algebraic solution.

Furthermore, Krulik (1980) argued that this interpretation is perhaps best seen in the distinction between the answer learners give to a problem and the procedures or steps they use to arrive at the answer.

Unlike Schoenfeld (1985); Krulik (*ibid)* argued that how one goes about learning the problem-solving process and how one should teach it is not fully understood. Krulik *(ibid)* suggested that learning to solve problems is the principal reason for studying Mathematics and solving word problems in texts is one form of problem solving, but learners also should be faced with non textbook, for they will spend the majority of their productive lives solving problems of this century.

2.6.2 Word Problems

My interest in word problems was triggered by the meaningless equations that Grade 10 Science learners often produced in response to mechanics tasks. This could be meaningless to me, but perhaps not to them. Thus, my focus is on the challenges that learners face with word problems in mechanics rather than the relevance they might have on the school curriculum.

According to certain studies, the structural make-up of word problems seems to have a barring on what learners do to solve them (Matthews, 1997; Nesher, Hershokovitz & Navotna, 2003). They argued that learners might respond to a problem according to the perceived structure of the problem, rather than from any particular understanding of the context.

Furthermore, Burton (1991:43) attributes difficulties that learners experience to *grammatical translation inhibitors* – she observed that even fairly elementary word problems involve translation of few-words sentences into mathematical equivalent and most learners fail to translate.

On the other hand, researchers are not certain of whose interest the word problems serve, are they relevant to learners, or the necessary components of the Science curriculum (Boote, 1998 and Toom, 1999) antagonist (Gerofsky, 1996 and Cooper & Dunne, 2000).

2.6.3 Reading the word problem aloud

Setati & Barwell (2006) argued that in South African classrooms, reading aloud formed part of the process of making sense of the problem. Educators read the word problem through in its entirety and finally asked the learners to read out the problem in unison sentence by sentence. These echoes, in line with my research project, that educators need to take cognisance of language problems when teaching word problems.

On the other hand, Olivares, (as cited in Lee & Jung, 2004: 271) recommends that English proficient learners, "be allowed to rely on their native language to make sense of Mathematics communication involved in word problems". The findings in this study showed that learners who are bilingual (Afrikaans and English) made errors were mainly 'deflective algorithms', careless, or process errors, but did not relate to not understanding the word problems.

2.7 Multi-lingualism

Gibbons (1991) argues that children who arrive in school with a strong command of the first language and a developed range of concepts in that language are thus in a very favourable position to learn English. Thus they are adding on the second language to the one they already have. It will seem that one of the worst times to switch language environments is around the age of five or six, when the comparative fragility of the first language does not support the learning of the second.

However, the situation for any bilingual children who have little mother tongue support is that once they start school their mother tongue is gradually replaced by English. Instead of adding on a language, they loose one. If their English is also not well developed, they can fall between two languages, with neither the first nor the second is adequate for learning in school. For these children it is important that schools not only support the development of English, but also do all they can to provide support for the mother tongue. Yet, many educators may feel that their previous training and experience have not sufficiently prepared them for teaching in a multilingual classroom.

In my view, both first and second language learning there is a gradual approximation to standard forms of grammar. Learners appear to develop hypotheses about language, which they later confirm or reject. Children in both cases might say, for example, "*I goed or runned,* having developed a hypothesis about the past tense ending *(I opened, therefore I goed)"* (Gibbons, 1991:8).

Similarly, Hatch (1983) as cited in Wong-Fillmore (1985), in an analysis of discourse data drawn from studies of language learning, found that the adjustment made by speakers for the sake of learners whether of first language or second language are quite similar. They are similar in the sense that the speakers tend to speak more slowly, enunciate more clearly, made greater use of concrete references than abstract ones, and used shorter and less complex sentences than they might otherwise. They also made greater use of repetitions and rephrasing than usual, and they accompanied their speech with gestures and demonstrations that give learners some extra-linguistic cues to aid in their understanding of what is being said.

Another major difference is the time frame within which the second language must be learned. English – speaking children begin their school – learning in a familiar language, which they have been hearing and using for around five years. They have had time and opportunity to use English constantly with a wide range of people and for a wide range of purposes. Whilst second language learners have also been acquiring language and advancing cognitively – but not in English. In an English-only school, they must make up for this gap as quickly as possible if they are not to be disadvantaged.

While proficiency in a spoken language is essential if children are to achieve their potential at school, most researchers argued that being immersed in a language and having access to good language models is of course important, but it is not in itself sufficient to develop language competence.

2.7.1 Being bilingual – is it an advantage or disadvantage?

Research indicates that there is some evidence to suggest that competent bilinguals - those with good skills in two languages have several advantages over monolinguals. Having two well developed languages appear to result in a greater capacity for lateral thinking and problem solving, and bilinguals seem to have greater facility in learning additional languages. The McGill University Psychologists Lambert & Peal (1962) suggested that where there is good literacy development in both languages, bilinguals on average score higher than monolinguals in verbal and non – verbal tasks of intelligence. Having a second language means having access to another world of people, ideas, ways of thinking and literature. Being a competent bilingual is a bonus as one researcher commented; bilinguals can think and say twice as much.

It is often assumed that children, particularly very young children, will simply 'pick up' a second language. Many educators comment on how quickly children with limited or no English learn to communicate with peers in the playground. And it is true that informal learning environments have a very influential role in the development of proficiency in English – particularly the everyday language that is essential for basic communication. Because the language tends to occur in situations in which the meaning is made clear through the visual context, and because there is usually a strong motivation for learners to learn, children tend to develop it quickly and seemingly quite effortlessly and certainly without deliberate and planned teaching.

However, playground language is very different from that educators use in the classroom and from the language that we expect children to learn to use. The language of the playground is not usually the language associated with learning in Mathematics, or Science or Social Sciences. The playground does not normally offer children the opportunity to use such language as: If we increase angle by five degrees, we could cut the circumference in equal parts. Nor does it normally require the language associated with higher order thinking skills (Bloom's taxonomy) such as hypothesising, evaluating, inferring, predicting or classifying. Yet these are the language functions, which are associated with learning and development of cognition, they occur in all areas of the curriculum, and without them a child's potential in academic areas cannot be realised. Unlike the language of the playground, the language associated with school learning takes a long time to develop. It is frequently quite abstract, and there may be fewer concrete visual clues to support meanings.

The Education Minister Naledi Pandor, announced in 2006 that her department is working on a plan to extend mother tongue instruction (MTI) from the first three years of schooling to the first six years. While few educationists opposed this move in principle – MTI is widely known to produce more literate and academically capable learners. Nevertheless, there are questions around how the proposed extension will be implemented, particularly in the light of the limited success of the existing three-year MTI policy. Educationists also argued that a lack of qualified staff to teach a diverse population and lack of MTI materials and textbooks are some of the major factors hindering the implementation of the MTI at large numbers of rural and township schools – where they are needed the most.

Furthermore, Pandor's announcement came in the wake of widespread concern around the slow implementation of the 1997 language policy for higher education (2002) – both of which were designed to promote multilingualism in the education sector to ensure that all South African languages are developed to their full capacity. According to Pandor this is viewed as an attempt to stop the dominant languages such as English and Afrikaans from acting as 'barriers to access and success'.

Furthermore, Pandor argued that the tendency in schools was to simply offer English and Afrikaans, which limited the government's ability to promote the values and principles of diversity and dignity that are part of the South African Constitution. She argues further that one cannot promote indigenous knowledge unless you teach children in their mother tongue, which is an integral part of the new curriculum statement. I agree with Pandor's suggestions because I believe teaching and learning in a foreign language could be one of the challenges faced by the majority of second language learners as evidenced in this research project.

Similarly, Dell (2007) argued that the gap between policy and practice seem to widen even further when it comes to extending mother tongue instructions in the first years of schooling in South Africa. She pointed out that as far back as 1953, UNESCO produced a report on the use of vernacular languages in education, which established MTI as a necessary foundation for literacy, and successful education. In the light of this, many researchers argue that it is now widely accepted that teaching children in a second language such as English will usually lead to subtractive bilingualism; a situation in which the first language is eroded by learning of the second. The result: both languages remain underdeveloped with serious implications for future cognitive development when learners are suddenly required to engage with Maths and Science in the later grades.

To qualify her argument, Dell *(ibid),* cited the Eddie Williams' study of children in Zambia and Malawi. The study showed that in Zambia they went straight to English, in Malawi the first three years learners were taught in a traditional language and the latter were more literate eventually in both languages.

However, MTI implementation remains difficult on many fronts. One of these is population diversity. This is particularly so in urban settings. It is not clear how we can determine mother tongue at any one institution, since we live in a multilingual society. At a particular school you may find that Zulu is not the dominant language because of a degree of migration that happens. Furthermore, a lack of African language textbooks and assessment materials means that any attempts at MTI, even in the most rural settings will invariably have to be mixed with English. Ironically, from my experience, parents are also standing in the way of MTI. They are motivated by the economic benefits of English language competence, often at the expense of educational benefits of MTI, parents are electing through the schools' governing bodies, for their children to be taught in English.

On the other hand, it is acknowledged that expecting learners to learn a new and difficult subject through a medium of a second language is unreasonable, giving them a task of mastering both Science and language. As seen above, it is frequently the most disadvantaged learners who are given this double task. Although much of the above argument suggests that being a second language speaker is necessarily a disadvantage, it is important to realise that bilingualism can be an advantage in concept acquisition as it helps the learner to see different representations of the same ideas (Swain & Cummins, 1979; Opoku, 1983). It should also be borne in mind that language problems in Science are not only confined to second language learners. Garraway (1994) pointed out the difference between the everyday language and Science and Mathematics terminology, which also leads to first language speakers learning a new language when learning Science. This view is echoed by situated cognition theorists such as Lemke (1997) who maintained that learning Science is learning to participate in a new social practice (context and / or environment).

Furthermore, Aikenhead & Jegede (1999) pointed out that learning of a new language is in itself part of another social practice, so learners learning Science through a second language are trying to become initiated into two social practices at once.

On the contrary, Wedekind (2007) argued that international learners who have poor English background, when they arrive at the university are able to pick it up quickly, work at a 'complex cognitive level' and sometimes surpass the academic performance of other learners.

Judging from the results of my learners, many learners are 'mimicking' – they have learnt the formulas but do not really understand them. This was especially evident in multiple-choice questions where most learners got the right answers but gave wrong reasons during interviews.

Most educators find themselves teaching learners instrumental understanding at the expense of relational understanding, all what they want is some kind of rules or procedures to get to an answer. As soon as this is reached, the learners latch onto it and ignore the rest. I believe we do this as Science educators as to cover up the syllabus, since the matric examinations are still standardised and exam driven. The standardised matric examinations force the educators to teach to task as echoed by Davis (1995). In contrast, Winch & Gingel (1996) suggested that there is absolutely nothing wrong with educator teaching to task, so long as tasks are reasonable and educators are sensible.

I fully agree with Winch & Gingel (*ibid*) that in teaching each part, some of what we teach is concerned with mechanical (rote learning or thin knowledge). Experience has revealed to me that thin knowledge usually leads to rich knowledge, if teaching has to be viewed as a journey from simple to complex. I also believe that in a real classroom situation the two, rich and thin knowledge should complement each other.

In conclusion, I think language is often invisible, as Science educators we should make it visible. Language is just like a pane of clean glass, you see through it easily if you are a first language speaker but if you are second language speaker, the windowpane is dirty or misty one cannot see through it clearly. Learning Science involves learning to see and talk in new ways (example, seeing salt as dissolving not just disappearing). Mathematics and Science are not natural language. Science language tends to compress meaning, it is dense unlike writing a novel where one can be expected to elaborate, one has to learn to be precise. Many researchers argue that this precise aspect of Science results in scientific literature being difficult to read, since it uses few words (Winch & Gingel, 1996; Aikenhead & Jegede, 1999 and Wedekind, 2007). I agree that Science turns processes into nouns, (for example, evaporation, fertilisation and condensation), because I also experienced this in teaching Grade 10s. In everyday English, evaporation is the process yet in Science it is a noun.

2.8 Mathematics? I speak it fluently.

Pimm (1991) argued that as educators, our primary concern should be encouraging and improving the communication of mathematical meanings, both between the educator and learner but also among learners themselves. Such communication about a situation or an idea can be verbal, pictorial or in mathematical symbols, where Pimm *(ibid),* assumed the latter two to be written. Mathematical ideas are often conveyed using a specialised highly condensed symbol system, which attempts to reflect relationships among the ideas by means of relationships among the symbols. In so doing, the symbol system acts as a kind of filter, dispensing with all but the essential elements involved, as by no means all the relationship among the ideas can be simultaneously represented. The learners must therefore come to understand this filtering process and become confident users of it. Thus we can see the dual nature of Mathematics, at once medium and message.

On the other hand, Olivier (1989) argued that in general it is not very useful to think of children errors in terms of low intelligence, low mathematical aptitude, perceptual difficulties or learning disabilities. He suggested that of course these factors play a role, but warned that if we are really concerned with helping individual children, such abstract ideas would not help – it is only when we work at the level of specific detail and get to know the specific roots of the mistakes (misconceptions), that we are able to help. It seems, Olivier *(ibid),* argued from a constructivist's perspective that misconceptions are crucially important to learning and teaching, because they form learner's conceptual structure that will interact with new concepts mostly in a negative way.

2.9 Conclusion

In this chapter, I have discussed the potential roots of the challenges faced by Grade 10 learners in sense-making of mechanics problems. Thus as educators, our primary concern should not only be to encourage the mathematical communication between educators and learners, but also among learners themselves.

To further minimise the challenges faced by Science learners, educators should code-switch where possible, teach reading and writing Science language. In addition to the above, educators ought to take cognisance of the role-played by learners' primary language, and the Science register in Science learning and teaching. The following chapter seeks to explore the research process and methodology.

Chapter three

Research process and methodology

3.1 Introduction to the chapter

Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of meanings people bring to them (Denim and Lincoln 1994b, cited in Dupuis 1999:45).

This chapter aims to explore the research process and methodology used in this research project.

3.2 Research Orientation

My research was located within an interpretive paradigm. Cohen, Manion & Morrison (2000:22) asserted that, "the interpretive paradigm is concerned with the individual, and the central endeavour in the context of the interpretive paradigm is to understand the subjective world of human experience". In this research study, I gained an insight of the challenges faced by learners during problem solving tasks in mechanics in Grade 10. My method was that of a single case study. Yin (2003) described a case study as an empirical enquiry that investigates a contemporary phenomenon within its real life context especially when the boundaries between the phenomenon and context are not clearly defined. According to Merriam (2001:27) "case studies do not claim any particular method for data collection or data analysis".

The mechanics task that was administered to the Grade 10s was of National Senior Certificate (NSC) examination standards. This task was given to 28 learners in 2006 of which 19 were girls. It should also be taken into account that 12 learners out of 28 were first (primary) language English speakers (E1) and the rest were either second language (E2) or third language speakers (E3).

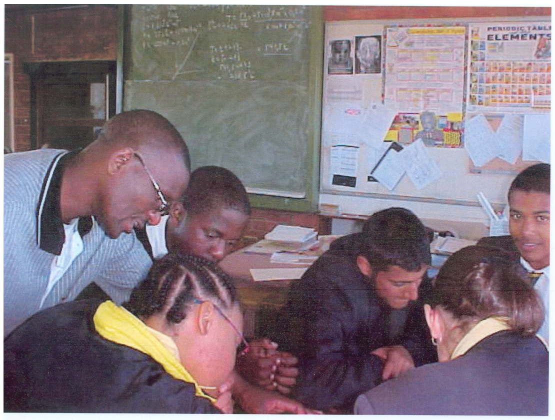
For this research project the E1 learners are those whose home language is English (Indians and Whites); E2 are those whose home language is Afrikaans (Mostly Whites and Coloureds) and E3 are those whose language is Nguni (Mostly Africans – Zulu, Sotho, Xhosa).

However, most of the learners discussed in this Chapter, share the following characteristics: they have been learning together for at least nine years, since they are mostly coming from Ixopo Primary School, our ex–model C feeder school, where English is taught as first language. All African learners never studied their home languages, but they studied and are currently studying English first language and Afrikaans second language. None of the learners are repeating Grade 10. This puts them almost on the equal footing or same background. Their age ranges from 14 to 15 years, and they have all passed Mathematics and Natural Sciences with at least 60% in Grade 9 to secure a place in the school's Science stream. In the light of all the above it is assumed that the learners under discussion have almost an identical academic background except home language.

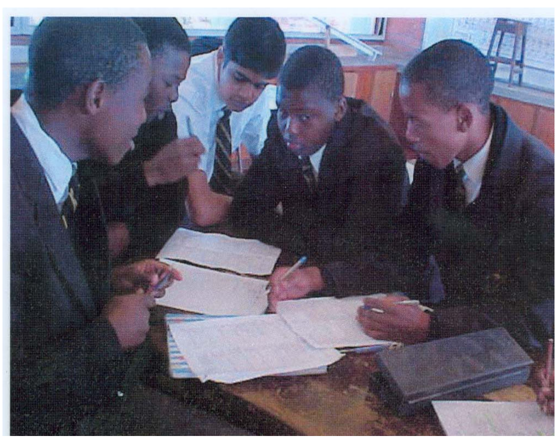
3.3 Research site and participants

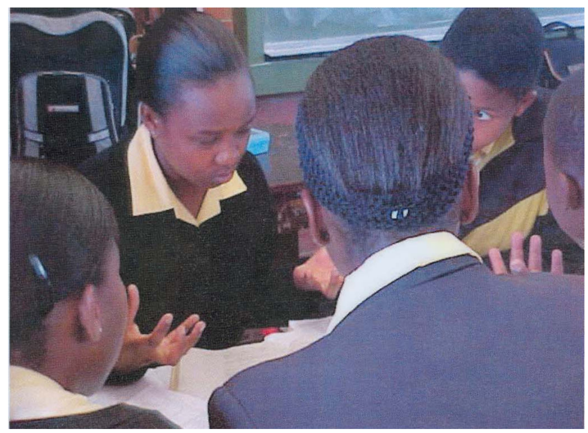
This research study was conducted at Ixopo High School, a mixed sex former model C school situated in a small town called Ixopo. I adopted the strategy of purposive sampling (Nachmias & Nachmias, 1996) with a focus on a Grade 10 Science class consisting of 28 learners (18 girls and 10 boys). From the 28 learners, a focus group of 6 learners constituted the case study. The group was made up of 2 high achievers, 2 mediocre learners and 2 low achievers. I also interviewed one Science/Mathematics teacher who was my critical friend in this study.

3.4 Pictures of Learners Brainstorming Mechanics Problems

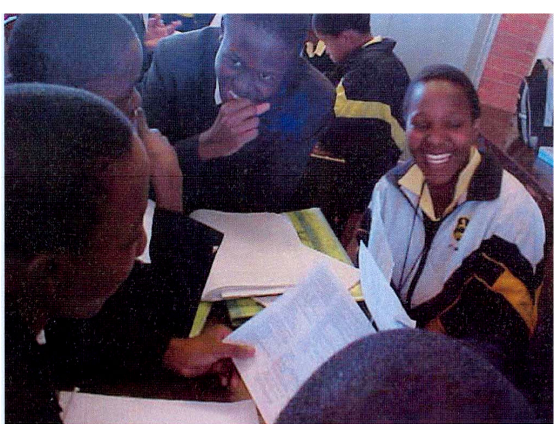


Educator Scaffolding on Mechanics Problems





Learners engaged in Mechanics Group Discussion



Learners look fascinated.

Learners making mechanics concept map

3.5 Methodology

"To answer some research questions we can not skim across the surface. We must dig deep to get a complete understanding of the phenomenon we are studying…" (Leedy & Ormrod, 2005:133).

3.5.1 Data generation techniques

In this research study the main data generation techniques I employed were: **task in mechanics** and **interviews (*semi-structured*** and ***focus (group)*** interviews). All the participants in this study were volunteers. The focus group interview with the learners was to explore their in-depth understanding and the challenges they experienced in making sense of the mechanics task. I also kept field notes in the form of a **research journal**.

3.5.2 Mechanics Task

To study some of the challenges faced by my learners I used a criterion referenced task as I did not intend comparing my learners' performance but rather required learners to fulfil a given set of criteria, predefined and absolute standard or outcome as proposed by Cunningham (1998). In line with Davis (1995) I used both multiple-choice and open-ended questions to explore how learners make meaning.

3.5.3 Interviews

Semi-structured interviews

I used semi-structured questions to explore in-depth learners' responses to the mechanics task. These allowed for a "more flexible approach that could be adapted to the personality and the circumstances of the person being interviewed" (Cohen, Manion and Morrison 2000). Also, semi-structured interviews were useful in that they facilitated freedom of expression and allowed the interviewer to probe or clear up misunderstandings. For the purposes of this study, I interviewed one Science educator who was my critical friend and whom I discussed with my interpretation of my learners' meaning making of the mechanics task. The interview was conducted after the task was critiqued and written. With the consent of the participant, interviews were tape recorded and transcribed verbatim so that data was not skewed.

Focus (group) interviews

The focus interview was pilot – tested on six Grade 11 learners, from diversified first language, two English first languages, 2 Afrikaans and 2 Nguni. A video camera was used. In arguing for a video camera Cohen *et al.* (2000) stated that there is a need to address the interpersonal, interactive, communicative and emotional aspects of the interview. They further argued that the interviewee could communicate non-verbally, by facial and bodily expression which may convey whether the interviewee is interested, angry, bored, agreeing or disagreeing. Whilst they were not arguing against transcriptions rather, the cautioned against researchers believing that they tell everything that took place in the interview.

According to Cohen *et al.* (*ibid*) some of the advantages of a video tape are that different kinds of data are recorded in the transcript of the audio tape. For example:

- What was being said?
- The tone of the voice of the speaker (harsh, kindly, encouraging).
- Reflection of the voice e.g. raising or falling
- Emphasis placed by the speaker
- Speed of the speech.

3.6 Data analysis and validation of data

To behold is to look beyond the fact, to observe, to go beyond the observation. Look at the world of people, and you will be overwhelmed by what you see. But select from that mass of humanity a well-chosen few and observe them with insight and they will tell you more than all the multitudes together. (Leedy & Ormrod, 2005:179).

The data was analysed using interpretational analysis, which is "a process of close examination of a case study data in order to find constructs, themes and patterns" (Winegardner, 2001:5) that address my research goal. Miles & Huberman (1994:21) and Patton (1990:372) have written about reducing the volume of information, identifying significant patterns and constructing a framework for communicating the essence of what the data reveals. I further analysed my data using concrete flows of activities: data reduction, data display and conclusion drawing/verification as suggested by Miles & Huberman (*ibid*). This involves the gleaning and reducing of information in the process of finding out how the results of the analysis can be crossed checked and validated.

3.7 Reliability and Validity

The main threat to internal validity was the possibility that prior knowledge of different learners could influence the results. To address this, Grade 9 learners' end of year examination marks were used as a pre-test to check for such differences. This was possible since all participants had passed the previous Grade in the same school. The average percentage scored in the pre-task and post-task differed by 0.3%. The distribution of scores remained practically unchanged between the two tasks with standard deviation between 14% and 15%.

Another threat, performance enhancement resulting from a change in teaching strategy, could not be excluded in the design of the research study. I assumed that the effect of change in itself would not produce a significant enhancement over a time of less than 3 months since I took over the participants from the previous Natural Science educator.

The pre-task and the post-task were set and marked by the same educators to ensure a uniform standard, thus avoiding the issue of inter-rate reliability. It could be argued that the researcher would be biased since the research study was done not only where the researcher lives but with one of his classes. To minimise bias, marking was done strictly in accordance with the departmental marking guidelines for Physics. Thus, giving marks to correct formulae, substitutions and answers. The researcher has been involved for more than eight years in marking departmental Grade 12 Physics examinations, thereby assuming marking would be according to the standard.

Furthermore, no additional credit was given for additional explanations or diagrams, ensuring that marks given to all learners would reflect only on the appropriate formulae and algebra. For validation of the task the researcher gave all marked scripts to two Science educators for moderation.

3.8 Ethical considerations

The permission to carry out the research was approved by the school principal, educators, parents and learners. The purpose of the study was explained fully to the participants. Respect for persons and respect for democratic values was maintained by explaining the arrangements for protecting privacy of participants (Bassey, 1995:15). Taylor & Bogdan (1998:40) asserted, "Qualitative research may threaten people's privacy and confidentiality". In the case of privacy, participants' informed consent to participate sorted and ethical statements were signed. All participants were kept anonymous and pseudonyms were used. Before the interviews, the interviewees were informed that they had a right not to answer questions they were uncomfortable with or they could withdraw from the interview process at any stage. All my data was kept in a secure place. The school was given a copy of a final report as per request. During the interview the participants were allowed to request that the tape recorder be switched off, if they felt like.

3.9 Conclusion

The formal semi-structured and focus (group) interviews and the task analysis of responses and the field note book records enabled me to compare and contrast information, which in turn helped me to make data more reliable and trustworthy. The focus interview and the semi-structured interview were designed and criticised by colleagues to include a Science educator then pilot tested and modified before being implemented *(see appendix H).*

However, I must point out that collecting data using the formal semi-structure and focus group interview strategies was not only challenging but fascinating as well. Furthermore, the task questions need to be well structured to cover all categories of knowledge (*see Bloom's taxonomy appendix J).*

The next chapter is a rundown of how results were collected from the task administered to learners after being pilot tested and modified by the colleagues.

Chapter four

Results

Any mathematical problem-solving performance is built on foundation of basic mathematical knowledge (Schoenefeld, 1985).

4.1 Introduction to the chapter

This chapter presents the results of a small-scale research project conducted at Ixopo high school from 2006 to 2007. Below are the questions and performance indicators on the task that was administered in 2006.

4.2 Performance Indicators

Task1 (*see appendix I*)

Multiple Choice Questions **Recommended Time: 14 min**

Write down the number and the correct letter only, e.g. 1.8 D:

1.1 The resultant of two forces acting at a point is maximum when the angle is

- **A.** 0^0
- **B.** 45^0
- **C.** 60^0
- **D.** 90^0
- **E.** 180^0

1.2 The following diagram represents 3 displacements: $\vec{x_1}$, $\vec{x_2}$ and $\vec{x_3}$

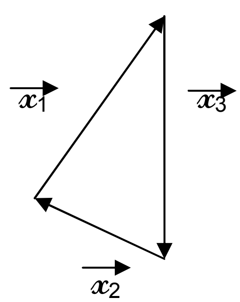


Fig:1.1

Which vector equation is correct?

A. $\vec{x_1} = \vec{x_2} + \vec{x_3}$

B. $\vec{x_1} + \vec{x_2} + \vec{x_3} = 0$

C. $\vec{x_1} + \vec{x_2} = \vec{x_3}$

D. $\overrightarrow{(x_1)}^2 = \overrightarrow{(x_2)}^2 + \overrightarrow{(x_3)}^2$

E. $\vec{x_3} = \vec{x_2} + \vec{x_1}$

1.3 Which of the following groups are all vectors:

A. Force, weight, velocity and displacement
B. Time, mass, energy and force
C. Mass, weight, velocity and energy
D. Speed, weight, mass and time
E. Time, mass, displacement and momentum

1.4 An aero-plane flies 1000 km in the direction of 180^0 and 750 km in the direction of 360^0. Its resultant displacement is

A. 750 km 180^0
B. 1000 km 180^0
C. 1500 km 180^0
D. 250 km 180^0
E. 1750 km 360^0

1.5 A man walks 4km in the direction 60^0 and then changes direction to 150^0 and walks further 3km. The man's resultant displacement is

A. 7 km 60^0
B. 4 km 150^0
C. 3 km 210^0
D. 5 km 97^0
E. 6 km 90^0

1.6 The resultant of two forces acting at point is minimum when the angle between the forces is

A. 45^0
B. 60^0
C. 90^0
D. 180^0
E. 0^0

1.7 The mass of a 10 kg hangs on the beam as shown in the sketch

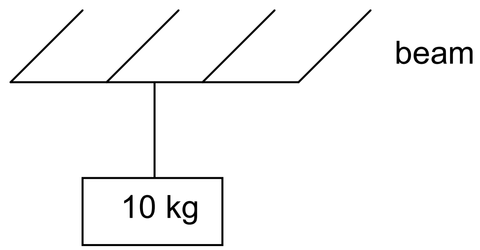


Fig: 1.2

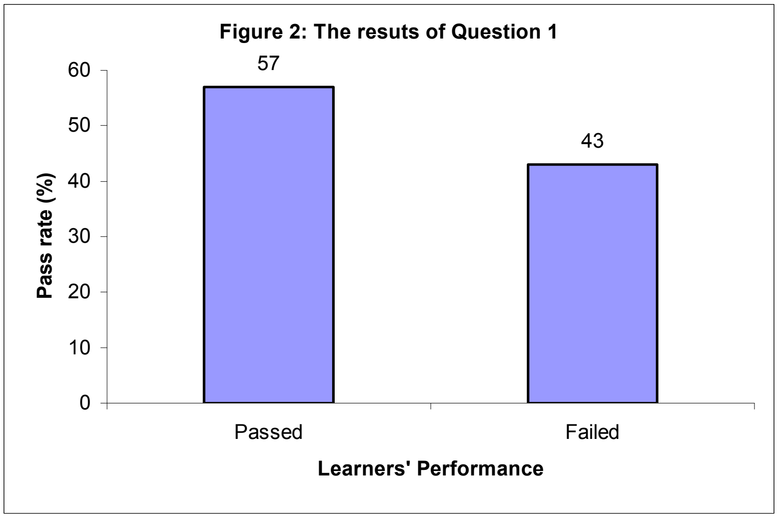
The tension in the rope is:

A. 0 N
B. 10 N
C. 40 N
D. 80 N
E. 100 N (3 X 7)

Figure 1: Table showing the level of questioning used in a Grade 10 mechanics task 1.

Level	**Type of Question**	**Weight of question per level**
Lower level	Knowledge	43%
	Comprehension	14%
Medium Level	Application	43%
Higher level	Analysis	00%
	Synthesis	00%
	Evaluation	00%

The learners' performance on task 1 is presented on the graph below:



Task 1 was composed of multiple choice questions which ranged from A to E, aimed at different levels of thinking. The knowledge testing questions (lower level of questions) had a lion's share of 57% of the total number of questions. As a result, I expected every learner to do well in this task. The other 43% of the total number of questions was an application type (medium level type of questions) whereby learners were to solve mechanics problems. However, as revealed by figure 2, only 57% passed this question and 43% failed.

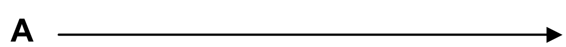
Task 2 (*see appendix I*)

Recommended time: 28 min

2.1

(a) Distinguish between a vector and scalar. (2)

(b) What can be determined from the following vector?



(4)

(c) An aero-plane alternately flies 300 km , 400 km and then 200 km in the direction of 60^0 , 130^0 and 270^0. Determine its resultant displacement. (4)

2.2

The winning woman in comrade marathon "up run" completes the 90 km from Durban to Pietermaritzburg in exactly six hours. Calculate her average speed

a. in km/h (3)
b. m/s (2)

2.3

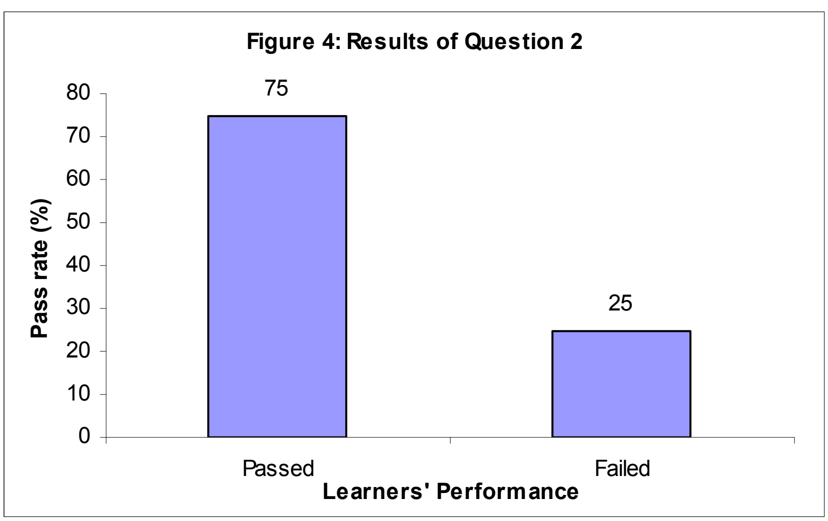
In which parts of the run described in question 2.2 is the runner's instantaneous likely to be:

(a) less than her average velocity? (2)
(b) greater than her average velocity? (2)

Figure 3: Table showing the level of questioning used in a Grade 10 mechanics task 2

Level	Type of Question	Weight of question per level
Lower level	Knowledge	00%
	Comprehension	32%
Medium Level	Application	26%
Higher level	Analysis	00%
	Synthesis	00%
	Evaluation	42%

The learners' performance on task 2 is presented on the graph below:

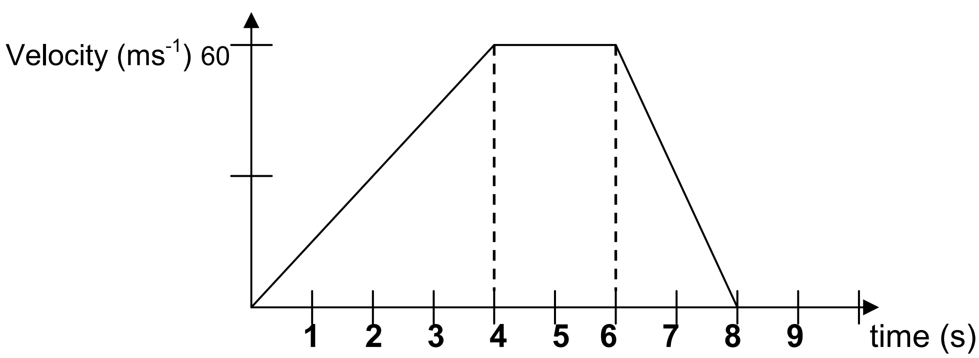


The task composed of 0% knowledge type questions, but 32 % and 26% application as well as 42% evaluation (Higher level of questioning). As indicated by figure 4, 75% of the learners passed and 25% failed. This could have been triggered by the low percentage of evaluation (higher level) questions, which constituted 42% compared to 58% of lower level of questions. In my experience in Science teaching, I have come to realise that the majority of learners find the lower level questions easier to answer.

Task 3 (*see appendix I*)

Recommended Time: 18 min

The following graph represents the relationship between velocity and time of a moving object. Use the graph to answer the following questions:



3.1
During which time interval did the object experience no acceleration? (2)

3.2
At which time interval did the object experience a velocity of 30 ms^{-1}? (2)

3.3
How long does the object take to come to rest? (2)

3.4
Calculate the deceleration of the object between 6th and 8th seconds of its movement. (5)

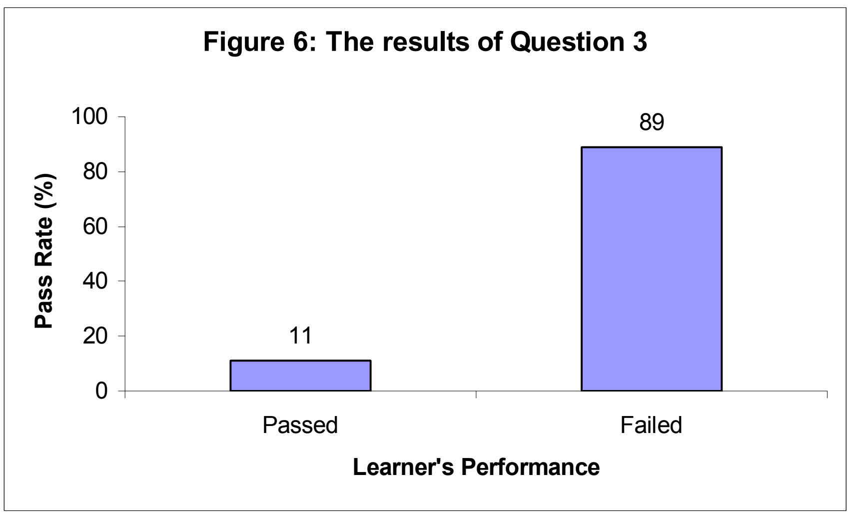
3.5
Calculate total displacement of the object. (7)

3.6
Calculate the average velocity of the object during the 8 seconds. (2)

Figure 5: Table showing the level of questioning used in a Grade 10 mechanics task 3

Level	Type of Question	Weight of question per level
Lower level	Knowledge	10%
	Comprehension	00%
Medium level	Application	10%
Higher level	Analysis	80%
	Synthesis	00%
	Evaluation	00%

The learners' performance on task 3 is presented on the graph below:



Most learners found this question very difficult since 89 % failed and only 11% passed. This could have been brought about by the fact that 80 % of this question was analysis (higher level of questions. Again in my experience in Science teaching most learners find higher levels of questions (analysis, synthesis, and evaluation) difficult to answer.

4.3 Conclusion

At this point, this study has served to un-earth what learners do and how they respond when they tackle mechanics problems. The chapter enabled me to gauge how learners position themselves with respect to mechanics problems, and how we expect them to be positioned.

The following chapter explores the responses given by the learners for the post-task.

Chapter five

Data analysis

> Ultimately, all fieldwork culminates in the analysis and the interpretation of some set of data, being it quantitative survey data, experiment, qualitative transcripts or discursive data…. Analysis involves "breaking up" into manageable themes, or patterns, trends and relationships. The aim of analysis is to understand the various constitutive elements of one's data through an inspection of the relationships between concepts, constructs or variables, and to see whether there are any patterns or trends that can be identified or isolated, or to establish themes in the data (Mouton, 2001:108).

5.1 Introduction to the chapter

The analysis of the results is drawn from a post-administered task, group discussions recorded on dvd, interviews as well as questionnaires. Finally, it describes in some detail the challenges faced by 28 Grade 10 learners in solving problems in mechanics post task.

5.2 Analysis of results

An analysis of the post-task indicated that it was of an appropriate standard for Grade 10 learners. In my view, most of the terminology used was appropriate and the structure of the task was one that learners ought to be familiar with. As also noted by the moderator the various cognitive levels of questioning were adequately covered and there was a fair distribution of the various levels of questions (Bloom, 1956).

The taxonomy is a hierarchy of learning skills. Bloom's Taxonomy was chosen because it normally includes language associated with low order, middle order and higher order thinking skills. It is like a pyramid, one should master the lower levels first before moving to the higher levels of thinking skills. Thus a good test, task or an examination should take cognisance of the Bloom's taxonomy.

Therefore in my research, a variety of question types and concepts tasked adequately covered the work covered. However, the comprehension and the analysis type of questions were simplified by the appropriate use of language and sketches in some cases.

Although, all learners completed the mechanics task – the quality of answers indicated that most learners did not spend much time reading each question thoroughly. It was also noted that although the language used appeared to be appropriate for Grade 10s – most learners whose first language is not English found words like beam *(question 1.7),* alternately *(question 2.1 c),* resultant displacement *(question 1.4, 1.5 and 2.1 c)*, interval *(question 3.1)*, average velocity *(question 2.3 b)*, deceleration (*question 3.4),* instantaneous *(question 2.3)* and tension *(question 1.7)* were problematic. An assessment of the responses to the interviews and the revision of the post task has shown a lack of understanding of such words (*see appendix I*). Although many questions were clear and unambiguous as far as I am concerned, most learners performed well in the following questions: 1.1, 1.4, 1.6 and 2.1 a, 3.2 and 3.3, but by contrast most learners fared poorly in the following questions: 2.2, 3.2, 3.4, 3.5 and 3.6.

5.2.1 Findings

2.2 (a) 18 learners were unable to convert km/h to m/s. This may be attributed to the fact that no such conversion was done during lessons.

3.2 6 learners could not interpret the data from a given graph. This could have been aggravated by poor mathematical application, a view shared by Warren (1984); Schoenfeld (1985); Pimm (1991).; and Tobias (2005).

3.4 25 learners especially L3 were unable to figure out the meaning of deceleration.

3.5 25 learners could figure out that the displacement on the graph is the area under the curve of the graph. The few who did, the quality of answers indicated a lack of conceptual understanding and poor computational/analytical skills. For instance, learners could not justify their correct answers.

3.6 The question has a bearing on 3.5. However there appears to be no emphasis on understanding mathematical procedures as evident in the whole of question 3 – graphs. Performance of candidates suggests that learners found this question most difficult. Although, many learners are familiar with area of triangles, trapezium and rectangles, most of them found this question challenging. In addition, to a certain extent, the language of the questions compounded matters, this view is also echoed by Gibbons (1990); Setati &

Barwell (1996); Probyn (2004) and Wedekind (2007); but contrasted by Wong-Fillmore (1995).

Perhaps it would help if Science educators spend some time teaching scientific terms and language. The results could also be suggesting that there is a need for educational practitioners to centralise language and give learners enough chance to use and explore scientific language, as suggested by Vygotsky (1978) that one can not have conceptual development without language. The following table contains some responses from one of the questions from the educator's questionnaire:

Some educators code-switch during their lessons. Do you sometimes code switch during your lessons? Substantiate your answer. For the purpose of this research, I shall refer to educators' name as E1, E2, E3, E4 and E5 (*see appendix D*).

Educator	Race	Age	Learning Area	Answer
E1	White, English	60-65	Science HOD	No, Biology textbooks and examinations are written in English. Understanding English is a prerequisite to pass.
E2	African - Coloured	50-55	Afrikaans	There is no substitute for Afrikaans, *finish en klaar*!
E3	African - Black	25-30	Maths/Science	Yes, when I want them to understand the concepts involved.
E4	White, English	40-45	English	No, If they are to learn a language, the best way is to speak and write it – offering them an alternative won't help them either after all, all their subjects except IsiZulu and Afrikaans are examined in English.
E5	African - Coloured	30-35	Afrikaans	Yes, when they don't understand especially the second language speakers I need to translate for them.

Sixty percent of educators said they will never code-switch during their teachings and forty percent are for code-switching. These results indicated that majority are not for code-switching. Researchers regard English as indispensable for communication of science internationally and for explaining clearly the concepts of Science.

On the other hand, the remaining forty percent were for code-switching. Farrad & Lee (1999) found that educators who share the languages and the culture of the learners often bring to the situation styles of teaching which are more appropriate to the learners' needs. For example, learners with more authoritarian culture may benefit from a more direct explicit approach which will be deemed to be more teacher-centred by outsiders. Educators do require knowledge of the nature of Science, which may at times be in conflict with local cultural values (Farrad & Lee, 1999). An interesting observation which was revealed through data analysis was that all educators who were against code-switching could not code-switch, whilst all those who were for, could.

5.2.2 Learners' misconceptions in mechanics

As educators, our interventions in the classroom are guided by some theory – be it conscious or sub-conscious of how children learn Science. Different educators hold different learning theories, and address learners' mistakes in different ways (Olivier, 1989). Olivier (*ibid),* has asked a question that many educators have avoided. Could it be all our frustrated efforts at eliminating errors, misconceptions or better still alternative conceptions are due to embracing an inappropriate theory? Although this was sufficiently covered in class, a large number of learners had misconceptions of vectors and scalars *(question 2.1.a* and speed *(question 2.2)*, displacement and velocity *(question 3.5 and 3.6 respectively)*.

Similarly, Bapoo (1997) argued that perhaps the greatest task of educators and this includes Science educators are tackling the mismatches that occur between what is taught and is learned by the learner. Bapoo (*ibid*) further argued that the learning process will be greatly simplified if a Science educator could confidently declare that the learners have taken aboard what they have been asked to learn.

In order to elicit learners' misconceptions, I used semi-structured interview and focus (group) interview to determine what can be done to help ease their difficulties.

Below is the summary table of the semi-structured interview responses. (*See appendix G*).
In your own understanding, what is the meaning of the word "beam" in question 1.7?

Learner	Response
MN	Could be like a pole --- Sir like something like high beam dangling.
MP	Beam is something where you keep food – Ja it keeps food. It's like an old trunk made of steel. And it was used in the olden days.
VK	Beam means something hanging from above – I think something hanging from the top.
QZ	Beam as in that used to put in food and the other one is for weighing mass.
SV	Beam is th…e uhm! It hangs on this thing called a beam – this thing over here *(point)*
WL	Its like something that is holding – something like a weight

MN's response was the closest answer to the question and followed by VK's and SV's. MP and QZ answers were similar in a way. MP and QZ are confusing beam with the bin, and both are English third language speakers (L3 learners). Therefore, in question 1.7 the L3 learners had a double task that the meaning of 'beam' and the concept of tension, before giving a response. (Skemp, 1976; Krulik, 1980; Wong-Fillmore, 1985; Gibbons, 1990 and Probyn, 2004) .

On the contrary some of their counterparts, English first language speaker (L1 learners) and the second language speaker (L2 learner) struggled with the concept of tension only before giving an answer (Wong-Fillmore, 1985; Gibbons, 1990*)*. However the analysis of the different responses given by the learners suggested that even L1 learners battled with English but to a lesser degree compared to L2 and L3 learners.

Thus the above-mentioned researchers argue that in addition children learning a second language at school are at a different cognitive and conceptual level. The L1 learners begin their school-learning in a familiar language which they have been hearing and using for around five years. They have had time and the opportunity to use English constantly with a wide range of people and for a wide range of purpose. On the other hand, the L2 learners have been acquiring language and advancing cognitively – but not in English. Thus in an English-only school they must make up this gap as quickly as possible, if they are not to be disadvantaged (Backhouse, 1982; Gibbons, 1990; Pimm, 1991 and Probyn, 2004)

Below is summary table of the focus interview (*see appendix H*).

1. What language would you prefer to use during Physics lessons?

Learner	Response
L1	English
L2	English
L3	English, but IsiZulu if I don't understand

Sixty six percent of the learners, which formed the majority, preferred to be taught Physics in English, because they could not code-switch, whilst thirty four percent, the minority opted for code-switching. The learners who opted for code-switching were all L3 learners. The study revealed that the learners opted between the two languages English and isiZulu.

Similarly, researchers argue that the situation for many bilingual children who have little mother tongue support is that once they start school the mother tongue is gradually replaced by English. Instead of adding a language, they lose one. Thus, if their English is also not well developed, they fall between two languages, with neither the first nor the second is adequate for learning in school. For these children it is important that schools not only support the development of English but also, do all they can to provide support for the mother tongue (Gibbons, 1990; Pimm, 1991; and Setati *et al.,* 2002; Probyn, 2004). What are some of the difficulties that you face during Physics lessons?

(*see appendix H*).

Learner	Response
L1	Coming up with the right equation and identifying the correct formula to use.
L2	I don't understand the Mathematics involved
L3	Some words are not popular ones, I mean common sir.

The analysis of the above responses indicates that learners lacked conceptual understanding as well as scientific terms. Similarly, Krulik (1980*)* argued that problem solving strategies involve posing questions, analysing situations, translating results, illustrating results, drawing diagrams and using trial and error. Krulik *(ibid)* further suggested that the need to be able to apply the rules of logic is necessary to arrive at valid conclusions, be able to determine which facts are relevant and be un-fearful of arriving at tentative conclusions and as well as willing to subject these conclusions to scrutiny.

5.3 Learner questionnaires regarding problem solving strategies (*see appendix K*).

The following questions were analysed: 1, 2, 3, 4, 5, 6, 9 and 15. The data revealed that 85% of the learners, to include those who did well in the task had NO for the answer for all the above questions. This confirmed the school of thought that suggested that instructional focusing on problem solving often ignores intellectual objectives and could encourage the learners to concentrate on algorithms instead of Physics. This school of thought further argued that success in calculating correct numerical answers does not necessarily imply a corresponding level of conceptual understanding. This school of thought suggested that learners learn to solve standard problems in Physics without applying conceptual ad interpretative knowledge (Schoenfeld, 1985; McDermott, 1991; Maloney, 1994; Warren, 1984; Dekker, 1997; Hobden, 1999; and Kim & Pak, 2000).

5.4 Conclusion

This chapter revealed the challenges encountered by Grade 10 Science learners at Ixopo high school and their attempt to solve the standardised mechanics tasks.

Furthermore, the chapter showed that the majority of learners (64%) were against code-switching and could not code-switch, whilst the minority (34%) were for and could code-switch. The findings also showed that 40% of educators were for code-switching and could code-switch, whilst 60% of educators were against it and could not code-switch.

The next chapter discusses the findings of the research project.

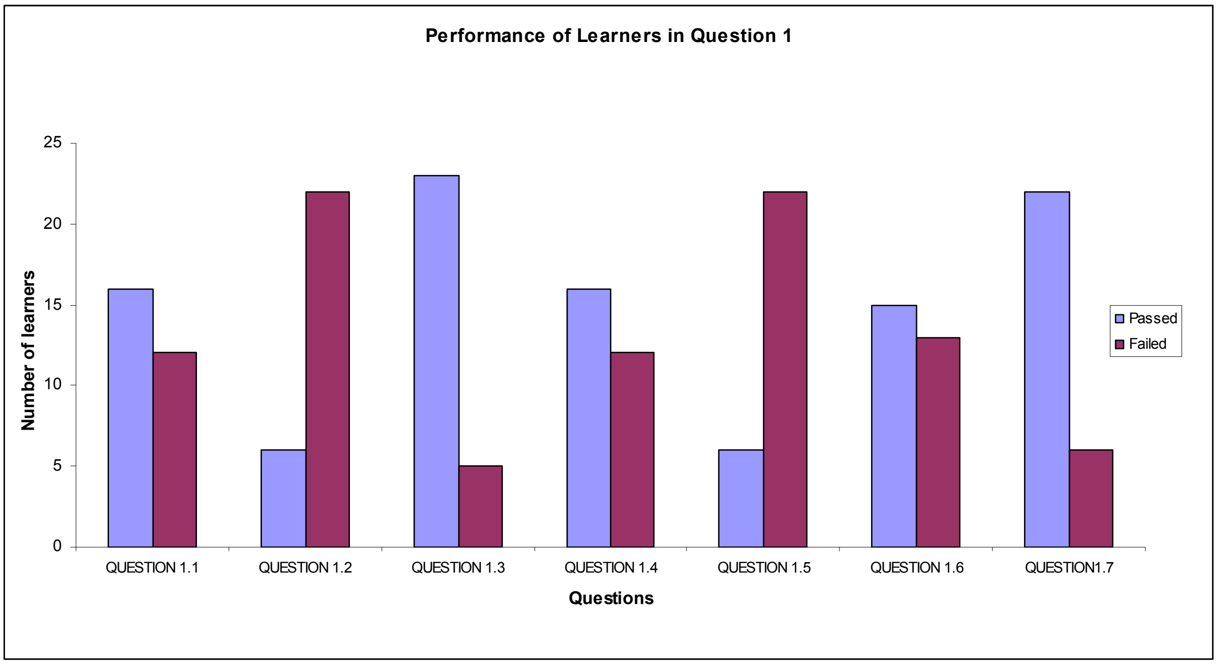
Chapter six

Discussion of findings

6.1 Introduction to the chapter

This chapter focuses on the discussion of the findings of the research project based on the mechanics task administered to the Grade 10 Science learners.

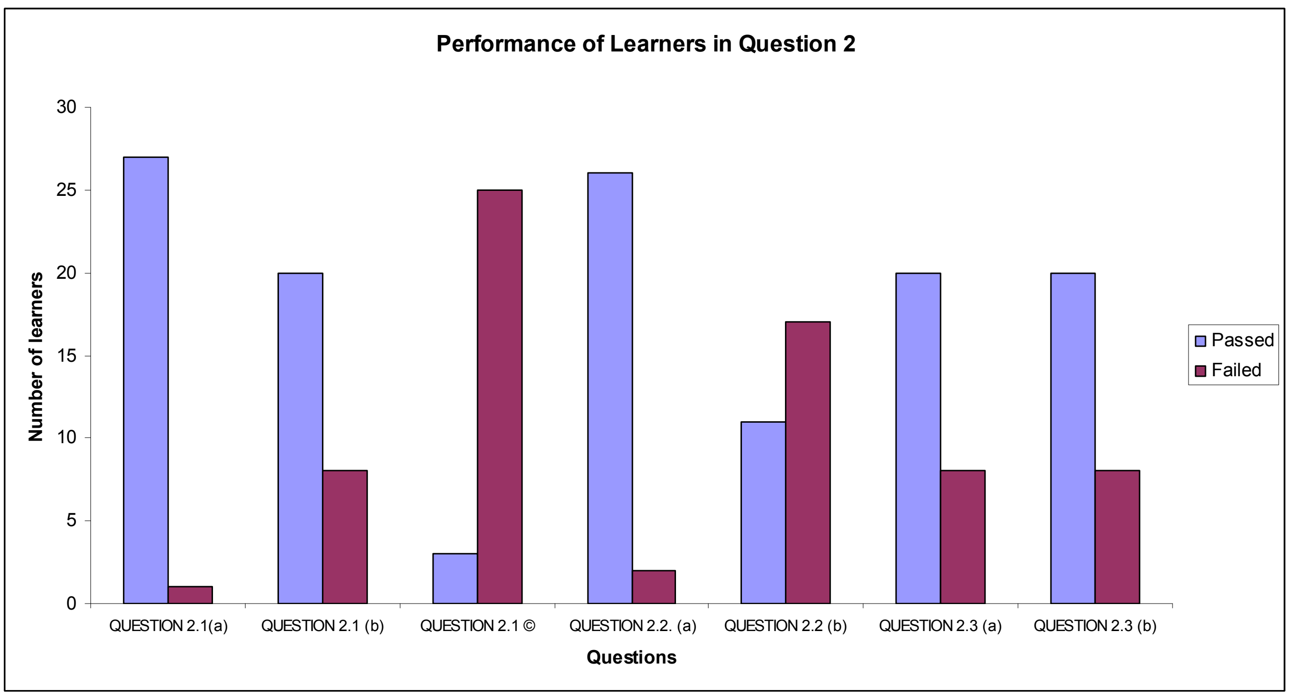
Task 1



Task1 (appendix I) was made up of 7 multiple-choice questions, and all questions are treated at length in this chapter. I thought the questions had a reputation of being difficult but most learners got 1.1, yet examining their problem solving performance (reasoning) through interviews revealed the breadth and depth of their misconceptions (wrong belief or opinion as a result of not understanding something). They confirmed that learners had, according to Schoenfeld (1985) little or no awareness of, or ability to use, mathematical heuristics. They indicated that the general issues of how one selects and deploys the resources and disposal – the issue of control – were far broader, and more critical than I had thought.

Furthermore, Warren (1984); Schoenfeld (1985) and Dekker (1997) argued that in most tasking situations learners are asked to work problems similar to those they have been trained to solve, and as a result, the context keeps them in the right arena, even when they are unable to solve the problems. Although the four problems tasked here were technically easier within learners' capacity and were technically easier than problems they solved in class, surprisingly some encountered problems. Whilst those who correctly answered could have guessed since they were multiple-choice based questions. This is also echoed by Schoenfeld *(ibid),* arguing that "in some cases, learners survived often with good grades by implementing well-learned mechanical procedures, in domains about which they understood virtually nothing" as stated by Warren (1984) and Dekker (1997).

Task 2

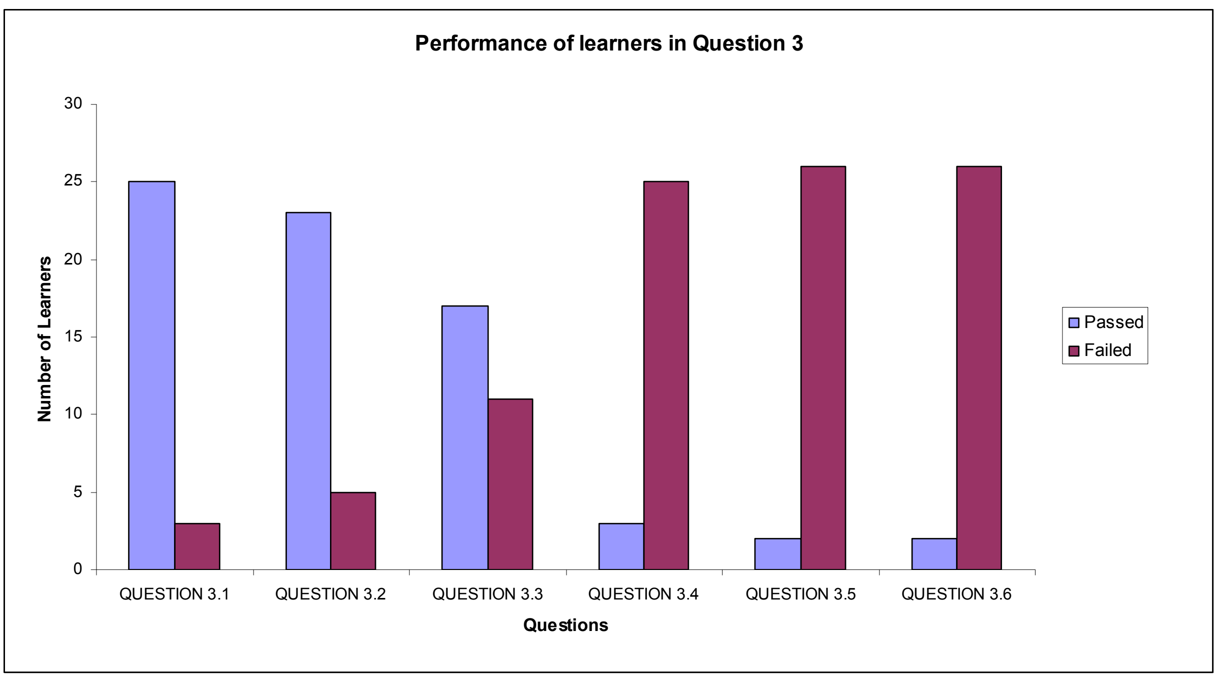


Question 2.1 (a), (b), (c) were got by almost everyone in this grade. The whole question 2.2 and 2.3 was passed by the majority with flying colours. The results of these questions reflected the operational definition of understanding as the ability to solve problems. Thus in agreement with Schoenfeld (1985) who suggests that a problem solving task is a

success if after instruction, the learners show markedly improved performance on a collection of problems that are not directly related to the problems studied in the course. In question 2.3 (a) and (b) the word concept ‘velocity’ was used where ‘speed’ would be more accurate.

Although the learners knew that velocity is a ‘vector’ none of them gave an answer with both magnitude and direction. This is also echoed by Warren (1984) who argues that consequently a very large proportion of learners will classify velocity and speed correctly in tasks and unfortunately the nature of distinction is not always clearly understood, nor is the terminology consistently used. Furthermore, Warren *(ibid),* argues that in innumerable problems, numerical values are given for ‘velocities’ without reference to direction by Science experts. He further argues that it cannot be expected, in the circumstances, that learners will attach any real importance to a distinction that is first introduced and then ignored.

Task 3



Question 3 consists of higher levels of questioning where learners are expected to analyse the problem, synthesise the solution and evaluate the solution. Twenty-five learners found these kind of questions very difficult and they tend not to do well in them. These findings indicate that a view of problems solving as an operational definition is too narrow. According to Schoenfeld (1985), whether one wishes to explain problem solving performance, or teach it, the issues are more complex. He further tabulated that one must deal with (1) whatever mathematical information problem solvers understand or misunderstand, and might bring to bear on a problem; (2) techniques they have (or lack) for making progress when things look bleak; (3) the way they use or fail to use, the information at their disposal; and (4) their mathematical world view, which determines the ways that the knowledge in the first three categories is used.

I thought learners would find this question and problem easy since their mathematical learning area had provided them, in the recent past with formal tools such as area of a triangle, area of a rectangle and area of trapezium that would enable them to solve question 3. I had the assumption that my learners had nearly adequate resources for problem solving, and I had provided enough practice on introducing problems so that their skills were serviceable according to Schoenfeld *(ibid)* but I was wrong.

6.2 Assessment

Davis (1995) pointed out that public examinations, psychometric tasks and other forms of assessment are supposed to be fair and objective. He further suggested that these aspirations are thought to be met in part through satisfaction of the technical criteria of reliability (the extent to which an assessment device gives consistent results over a range of occasions) and validity (the extent to which the device measures what it is claimed to measure). He further pointed out that multiple choice may be reliable but it does not tell you whether the learners understand the concepts or not, reliable but not valid. Similarly, Skemp (1976) identified this as instrumental understanding – learning rules without understanding (rote learning). By contrast, Davis *(ibid),* argued that open items or tasks are too flexible and marking become subjective, tasks become valid but not reliable. In arguing for criterion-referenced assessment (CRA), Davis argued that there is no CRA that can achieve both reliability and validity at the same time.

In line with Davis (1995) I have also noted that the majority (57%) of my learners passed the multiple-choice questions. The disappointing part is that they could not justify their answers during the interview. This could be indicating, in Davis' view that the multiple-choice questions were reliable but not valid.

On the other hand, questions such as 2(a) and 2(b) which were open items were too flexible and marking became subjective. It could be argued that questions were valid but not reliable, since different educators could give different marks for the same answers like it was the case with my moderator and me. According to Davis *(ibid),* if one wants objectivity and consistency one should go for multiple choice, which does not cultivate rich knowledge or high order skills. On the same note, he pointed out that it is important for learners to give facts that are related or connected or better still linked. There has to be correlation of facts or ideas and order is important in putting down facts. Skemp (1976) called this relational understanding (knowing what to do, when and why). This in Davis' view can only be achieved through the use of open items or tasks, which cultivate rich knowledge. However, Davis (1995) suggested that a memorandum should be provided for the examination or task to improve reliability and validity to a certain extent.

In conclusion, this chapter has shown different problems experienced by learning and writing a mechanics task. Having considered both sides of Davis' argument and evidence from my task and interviews, I have come to realise that a balanced task should be reliable and valid at the same time. The reliability and validity of any task or exam can be achieved through combining multiple choice and open tasks.

6.3 Summary of Findings

Triangulation may be defined as the use of two or more methods of data collection in the study of some aspects of human behaviour… Triangulation attempts to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint…(Cohen *et al.,* 2000:112)

Learners who qualified to be in the Science stream and were willing participants, indicated that they were biased to Science and relatively confident about their abilities in the learning area. Yet, examining the challenges faced by the learners in sense-making of mechanics problems, revealed some unpleasant realities. The task given to learners to solve was certainly within their capability and generally easier than problems solved in class, yet most of the learners performed below my expectations.

A close examination of these learners' challenges in this research study revealed that:

- It should be borne in mind that language problems in Science (mechanics) are not confined only to second language learners. Thus, Pimm (1981); Gibbons (1990); and Garraway (1994), pointed out that the difference between everyday language and Science terminology also leads to first language learning a new language when learning Science.
- The research also acknowledged that expecting learners to learn a new and challenging subject through the medium of second language gave them a double task of mastering both language and content, as suggested by Wong-Filmore (1985) and Probyn (2004).
- Failure to make meaning of Science terminology, to include symbols, signs and equations inevitably impair communication in Science.
- Judging from the answers provided in the interviews many learners were 'mimicking' – they learned the formulae but they did not really understand them. This was evidenced especially in the multiple-choice questions where learners got the right answers but gave wrong reasons for choice during interviews. Most of the solution strategies that the participating learners employed were straightforward procedures that they had learnt in class. The examination of the data suggested that learners relied mostly on procedural understanding at the expense of conceptual understanding (Skemp, 1976; Warren, 1984; Schoenfeld, 1985; Greeno, 1989; McDermott, 1991; Dekker, 1997 and Boote, 1998).
- In line with Schoenfeld (1985), the close examination of the data suggested that in some cases learners survived (often with good grades!) by implementing well

learnt mechanical procedures, in domains about which they understood virtually nothing.

- About 18 out of 28 learners (64%), revealed through both interviews and tasks answers that they lacked conceptual understanding of the following quantities: *speed, velocity, deceleration, displacement, distance, instantaneous speed, beam and tension* (Pride, Vokos & McDermott, 1987; McDermott, 1991 and Hobden, 1999).
- It is also important to highlight that the misconceptions all surfaced during the structured interviews. What surprised me is while misconceptions were alive and influencing learners' problem solving, they had no apparent detrimental effect on calculation, so they may not even be detected or be overly concerned about them as suggested by Schoenfeld (1985) and Olivier (1989).

6.4 The significance of the results

The results of this study have contributed to the investigation of the challenges facing Grade 10 learners in making sense of mechanics problems in the following ways:

- Firstly, the task was not seen as a means of assessing learners' intelligence or capabilities, but as a tool that created opportunities for teaching and learning. The significance of the study lies mostly in the analysis of learners' answers, which in turn reflected the problems they face in mechanics.
- The significance of the study has informed educator practice that Science vocabulary is sometimes at odds with English vocabulary.
- Thirdly this study, in line with outcomes based teaching has shown that learners need to be encouraged to think rationally as opposed to instrumentally.

6.5 Potential areas for future research

While the relationship between Science and language is well known and often talked about, details of the precise effects of usage of language in Science is not well understood. Reading as part of the learning process is an area that is little understood or researched in Science education. (Davies & Greene, 1984 and Wary & Lewis, 1997). It is commonly observed that the genre (style of writing) in Science text can be much more difficult than that associated with the subjects in humanities such as a narrative form in English to which learners are highly receptive (Davies & Greene, 1984). It is for these reasons that I have decided to engage in this study. Another future area where research is needed is on the exploration of differences between everyday language and science terminology.

6.6 Limitations of the study

On reflection, there are quite a number of limitations and shortcomings on this study. Douglas (as cited in Taylor & Bogdan, 1998:28) argued that "researchers should stay away from areas in which they have deeply felt emotions as this might affect the quality of the study". Since making sense in Science is close to my heart, there is a potential risk that my observations could be clouded by emotions, thus making me to see what I want to see or would like to see happening. To validate this study, at key points in the process I discussed my findings with other Science educators from Ixopo high school for their reflections and comments. These discussions were honest and fruitful in the sense that I managed to use them in this research.

I did not ask the learners to give explanations to their answers, so reading and writing skills and conceptual understanding could not be detected. This is one of the limitations of the research study.

Furthermore, one of the shortcomings of this research study was the sample size. The task solutions of only 28 learners from one school were analysed and I feel the size is not big enough to give a true reflection of the challenges faced by the Grade 10 learners in the province, let alone our country.

Another limitation of the study was that only six learners out of twenty-eight who took part in the overall study were interviewed. Nevertheless the semi-structured interviews continued to be a powerful tool to gain insight into the learners' construction of the knowledge and the challenges they are faced with in sense-making of mechanic problems.

6.7 Conclusion

The journey my learners and I took through the world of mechanics, has allowed me to be better informed, and perhaps more sensitive to the challenges that learners face in sense-making in mechanics. This mixed method (quantitative and qualitative study) was situated in the interpretative paradigm and was underpinned by constructivism as a theoretical framework. The data used to answer research goals were collected using three instruments. The first instrument was a task that was used to gather necessary information concerning the challenges faced by Grade 10 learners in mechanics. This instrument was used to measure learners' meaning-making in mechanics. The findings have shown that learners were not fluent in the Science register especially second language English speakers and this was also echoed by Pimm (1981) & Gibbons (1990)

Educators pointed out during the semi-structured interviews (*see appendix E*.) that in both English and Science subjects, even the first language speakers were battling with English, but to a lesser degree. This is in line with Garraway (1994), who suggested that it should also be borne in mind that language problems in Science are not confined to second language learners only. He further pointed out the difference between everyday language and Science or Mathematics terminology also leads to first language speakers learning a new language when learning Science. Thus the study also demonstrated that it should be recognised that the scientific language used in everyday life might be at odds with school Science; therefore it is important for Science educators to teach Science terminology during Science lessons.

The study has illuminated the challenges of verbal communication (spoken, written words) and non-verbal communication (graphics, drawings, pictures, signs and symbols and mathematical equations). These challenges are further echoed by Pimm (1981); Lemke (1997) and Dhillon (1998), who argued that Scientists attempt to communicate by using highly specialised language – the language of Science that incorporated more than just words, they draw on multitude of signs and symbols (a multi-semiotic system) to communicate their ideas: this includes charts, graphs, diagrams, mathematical signs and symbols, equations as well as Natural Sciences.

The research suggested that the other challenges were learners' errors and misconceptions as a result of prior learning. In line with Olivier (1989), errors and misconceptions should be viewed as a natural result of learners' efforts to construct their own knowledge. He further argued that these misconceptions are intelligent constructions based on correct or incomplete (but not wrong) previous knowledge.

Similarly, Kearsey & Turner (1999) showed how subjecting textbooks to genre analysis can assist in judging the accessibility. Again, their expository nature makes texts inaccessible to learners leaving educators to mediate what Lemke (1992) refers to as 'the ponderous style of textbook Science'. On the hand O'Toole (1996) explained that it is no accident that scientific prose is so compact. Scientists consider it necessary in order to communicate accurately with their peers. However, learners in school are not the peers of the scientists. Nor are they even apprentice scientists but are more often than not future citizens aspiring to be scientifically literate.

In light of the above challenges faced by the learners in mechanics, I conclude that as Science educators we need to create classroom atmospheres that are tolerant to errors and misconceptions and exploit them to enhance learning of mechanics, a view also shared by Olivier (*ibid).*

6.8 Reflections

Every worker needs tools. The carpenter needs a hammer and a saw; a surgeon, a scalpel and forceps; the tailor, pins and scissors; and the researcher, an array of means by which data can be collected and made meaningful. The tools of research facilitate the ultimate goal of research itself: to derive conclusions from a body of data and discover what was hitherto unknown (Leedy & Ormrod, 2005).

When I started my research I thought it was going to be like a walk in a park. Little did I realise what I was getting myself into. In my pilot study all my tape recordings were not clear at all, and I had to resort to my field notebook. The video was clear although at first, the learners were responding to the video instead of the group interviews.

I also learnt the hard way that a stranger sitting and observing is a potential intruder for both the educator and the learners. This also disturbed the learning environment and inhibited good teaching and learning practices.

The language issue is quite a broad topic, trimming it down was not easy. I also came to terms with the fact that being a researcher is not a privilege. For one has always to touch people's innermost feelings. In the light of the above fact one is bound to dwell in people's private lives. To be able to do this, people have to trust you and you have to trust them if research is to succeed.

I also realised that the more information I had the more I got confused and staying focused was my setback. Gleaning of information was quite challenging too. Nevertheless, if given another chance I will do it again. The experience I got in conducting this research project is priceless. I can only hope the same could be true to all the participants as well as the readers!

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APPENDIX A Permission Letter to the Principal

G23 ERF 8845
Coulter Street
Section 6
Kokstad
4700
24 April 2006

The Principal
Ixopo High School
Private bag 554
Ixopo
3276

Dear Sir

REQUISITION TO INVOLVE GRADE 10 SCIENCE CLASS IN SCIENCE RESEARCH PROJECT.

I am hereby requesting a permission to involve the Grade 10 Physical Sciences learners in my master of education (science) research project. The research is based on the new FET programme and is part of their curriculum and shall be done during science periods.

I am looking forward to receive a positive reply from you at your earliest convenience.

Thank you in advance.

Yours sincerely,

Mr. J. Malunguza

(Science Educator)

APPENDIX B Principal's Response

IXOPO HIGH SCHOOL

"OUR SCHOOL - OUR FUTURE"

ESTABLISHED 1895

PRIVATE BAG 554 IXOPO 3276 TEL 039 -8 341063/4 FAX 039 -8341808
E-MAIL: ixopohigh@ixopohigh.co.za
ihsaccounts@intekom.co.za

24 April 2006

Mr. J. Malunguza
G23 Erf 8845
Coulter Street
Section 6
KOKSTAD
4700

Dear Mr. Malunguza

I hereby grant you permission to conduct the research project with the Grade 10 Physical Science learners.

Yours faithfully

MR. DL LINDE
PRINCIPAL

PRINCIPAL
IXOPO HIGH SCHOOL
PRIVATE BAG 554
IXOPO 3276

APPENDIX C: INVITATION TO FELLOW EDUCATORS.

G23 ERF 8845
Section 6
Coulter Street
Kokstad
4700

Tel: 039 834 1063/4 (w)
Cell: 072 3451 037

Dear Fellow Educator

INVITATION TO COMPLETE A RESEARCH QUESTIONNAIRE FOR MY M.Ed. (SCIENCE) RESEARCH

The role of language literacy (listening, speaking, reading and writing) in promoting the Grade ten learners' conceptual understanding of mechanics: A case study.

I am completing my M.Ed. (Science) at Rhodes University in Grahamstown and would like your assistance with the questionnaires.

Recent studies have suggested that language has a very important role to play in the learning of Science, but there is relatively little research that pertains specifically to listening, speaking, reading and writing in Science education. My research is an attempt to ascertain the role that listening, speaking, reading and writing may have on promoting learners' conceptual understanding.

Attached is the inventory of questionnaires with two sections. You will need about 10-15 minutes to complete the questionnaires. You will need to complete the questionnaires honestly and sincerely, as the validity of the research will depend on your honest responses. You will also need to complete a consent form prior to the distribution of the questionnaires.

Please do not write your name or the name on the questionnaires. All the responses will be treated as strictly confidential. Demographic details requested provide important information for comparisons to be made. You are assured that this is not a subtle attempt you or your school.

Thank you for agreeing to participate in my research. I am most appreciative of your willingness to assist me in this fascinating task. The research findings will be available to you on request.

Yours faithfully,

____

Mr. Malunguza J. J ((M.Ed. (Science) Student Researcher)

Date:…………………

APPENIDIX D: EDUCATORS' QUESTIONNAIRE

SECTION A
Demographic Variables
Please place a cross in the block that is most applicable to you.

1. **Gender**

Male		Female	

2. **Years of teaching experience**

1-10 yrs		11-20 yrs		21 – 30 yrs		31 yrs -	

3. **Age in years**

20-30 yrs		31-40 yrs		41 – 50 yrs		51 -60 yrs		61 yrs	

4. **Current post level**

Educator		Head of Department		Deputy Principal		Principal	

5. **The type of school you are teaching at**

Ex-Model school	Section 21 Urban State School	Section 21 Rural State School	Non Section 21 State School	Non section 21 Rural State school
Farm School	Independent School			

6. **The phase(s) you are teaching**

Foundation Phase (Grade 1-3)	Intermediate Phase (Grade 4-6)	Senior Phase (Grade 7 –9)	FET Phase (Grade 10 –12)	Other:

If other, specify ___________________

7. **Home Language**

Afrikaans		English		Xhosa		Zulu		Other	

If other, specify ___________________

8. **Highest level of Education**

Grade 12 or lower	Teaching Diploma	Degree	Degree plus a teaching diploma	Postgraduate degree	Postgraduate degree plus a teaching diploma

SECTION B

1. What is your greatest challenge in teaching your discipline?

____

____

____

2. Do learners always understand everything you teach them?

YES ☐ NO ☐

3. What factor(s) contribute to the understanding referred to above?

____

____

____

4. Some educators code-switch during their learners. Do you sometimes code switch during your lessons? Substantiate your answer.

____

____

____

5. What do you think determines how well learners learn in your discipline?

____

____

____

6. If you were a learner what suggestions would you give to your educator to help you understand and remember what you have been taught?

____

____

____

APPENDIX E: LEARNERS' QUESTIONNAIRES

DEMOGRAPHIC VARIABLES

Please put a cross in the block that is applicable to you in 1 and 3.

1. Gender Male ☐ Female ☐

2. Age 13 –14 ☐ 15 –16 ☐ 17 – 18 ☐ 19 and Above ☐

3. Home Language Afrikaans ☐ English ☐ Xhosa ☐ Zulu ☐ Other ☐

If other, please specify ___________________________

QUESTIONS

1. What is your greatest challenge in Science?

   ____

   ____

2. Do you always understand everything you are taught in Science?

   YES ☐ NO ☐

3. What factor(s) make you to understand or not to understand everything you are taught in Science?

   ____

   ____

4. In what language would you prefer to learn Science and why?

   ____

   ____

   ____

5. If you were Science educator (teacher) what would you do in order for Science learners (pupils) to understand and remember what they have been taught in Science?

   ____

   ____

   ____

APPENDIX F: CONSENT TO PARTICIPATE IN M.Ed. (Science)

To Whom It May Concern:

I ………………………………………………… (full name) hereby give my consent that my response to the questions in the two sections of your research inventories namely: the supply of demographic information and the role of language in teaching and learning can be used by Mr. J Malunguza for his M.Ed. (Science) research.

I understand that I am a voluntary participant. I am confident that my responses will be treated as strictly confidential.

Signed at ____________________ on this day ___________________ of _____ __________________ 2006.

____

Signature of the respondent

____

Researcher's signature

APPENDIX G: LEARNERS' INTERVIEWS

QUESTIONS:

1. In your own understanding, what is the meaning of the word "beam" in question 1.7?
2. What do you understand by the term "average velocity" in question 2.3 (b) and 3.6?
3. Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?
4. The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

RESPONSES:

Interviewer: J. J. Malunguza

Interviewee 1: **MN** (English 1st language, Afrikaans 2nd language) – High Achiever

J.J: In your own understanding, what is the meaning of the word "beam" in question 1.7?

MN: Could be like a pole --- Sir like something like high beam dangling.

J.J: Dangling you say that's what you would say.

MN: Yes! *(expressing with hands)*

J.J: What do you understand by the term "average velocity" in question 2.3 (b) and 3.6?

MN: It could be a speed over a certain distance.

J.J: How would it differ with ordinary velocity?

MN: Pretty much the same – uh! M like its very similar

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

MN: It is how long it takes to slow down or stop

J.J: The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

MN: M… Uh! The runner himself - when like the runner going to do something.

J.J: O' right MN, thanks very much.

Interviewer: J. J. Malunguza

Interviewee 2: **MP** (Xhosa 1st language, English 2nd language, Zulu 3rd language)

J.J: In your own understanding, what is the meaning of the word “beam” in question 1.7?

MP: Beam is something where you keep food – Ja it keeps food. Its like an old trunk made of steel. And it was used in the olden days.

J.J: Ok MP, let’s look at the following question.

J.J: What do you understand by the term “average velocity” in question 2.3 (b) and 3.6?

MP: Average velocity is the midpoint by the two numbers or …

J.J: Or what?

MP: May be the centre of the graph.

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

MP: I must calculate instantaneous velocity. I must calculate the middle or average velocity.

J.J: How different is it from ordinary velocity?

Long pause…

J.J: How will the two differ?

MP: I don’t know Sir.

Thank you MP.

Interviewee 3: **VK** (Zulu 1st language, English 2nd language)

J.J: In your own understanding, what is the meaning of the word “beam” in question 1.7?

VK: Beam means something hanging from above – I think something hanging from the top.

J.J: What do you understand by the term “average velocity” in question 2.3 (b) and 3.6?

VK: Velocity is …

J.J: Not velocity but average velocity.

VK: Average velocity could be something of measurement when you run or distance calculated doing something or after you have a number of exercises or task and then calculate average of that task or those tasks.

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

VK: Deceleration is the decreasing of the speed of that you were doing or…

J.J: Or what?

VK: Or could be deceleration that's the only answer I have basically decreasing you acceleration. Good.

J.J: The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

VK: I think this one I am not sure of the meaning of the instantaneous. Not sure of the word I thought it was like in start – probably not changing meaning not increasing or decreasing going at one pace.

J.J: Thank you VK.

Interviewee 4: **QZ** (Xhosa 1st language, English 2nd language)

J.J: In your own understanding, what is the meaning of the word "beam" in question 1.7?

QZ: Beam as in that used to put in food and the other one is for weighing mass.

J.J: Are you saying, the other one is for weighing, weighing what?

QZ: Anything that can be put in it.

J.J: What do you understand by the term "average velocity" in question 2.3 (b) and 3.6?

QZ: Average velocity is uh..!

J.J: What do you understand by that?

QZ: Average velocity?

J.J: Yes!

QZ: Average is a thing or a number like say you write a test you get a number below the number say it is a test out of 40, you get 19. It means you did not pass well.

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

QZ: Deceleration is the speed at which one is traveling and how low it can go.

J.J: Alright, uh…uh...!

J.J: The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

QZ: Instantaneous velocity is the velocity at which one is moving with.

J.J: How does it differ from velocity?

QZ: Do not differ very much it's almost the same thing.

J.J: Thank you very much.

Interviewee 5: **SV** (Xhosa 1st language, English 2nd language)

J.J: In your own understanding, what is the meaning of the word “beam” in question 1.7?

SV: Beam is th….e uhm! It hangs on this thing called a beam – this thing over here (*point)*.

J.J: Ok, how will you describe the beam to someone on the phone?

SV: It hangs on something like a beam, if he does not understand I will show them. The word beam is not essential all you need to do the problem is the force not the beam.

J.J: What do you understand by the term “average velocity” in question 2.3 (b) and 3.6?

SV: Average velocity – speed with direction – I think that’s what average velocity means.

J.J: How does it differ from velocity?

SV: The formula is nearly the same but the meaning is the same. Both are measured in ms^{-2}, no ms^{-1}.

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

SV: Deceleration – its like opposite of acceleration and you go down you coming to a stop not gonna stop. Ja you not stopping but coming to a stop.

J.J: The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

I think in my understanding instantaneous velocity – instantaneous velocity – speed or something. No just speed it means speed or change to velocity.

J.J: Thank you so much.

Interviewee 6: **WL** (English 1st language, Difficulty with Afrikaans 2nd language)

J.J: In your own understanding, what is the meaning of the word “beam” in question 1.7?

WL: Its like something that is holding – something like a weight.

J.J: What do you understand by the term “average velocity” in question 2.3 (b) and 3.6?

WL: Average velocity means how much pressure, you put something Sir, It refers to weight.

J.J: So weight and pressure is one and the same thing?

WL: Yes, sir!

J.J: Question 3.4 expected you to calculate deceleration of the object. What is the meaning of deceleration in your own understanding?

WL: Deceleration is like Sir, you not accelerating at all or car is getting slower, stops at 8s.

J.J: The task question, in 2.3 invites you to calculate instantaneous velocity. Explain the term instantaneous velocity.

WL: Instantaneous velocity – is like velocity – is like velocity that doesn't stop. It something like pressure (*used a lot of gestures)*

J.J: Thank you very much for your time.

APPENDIX H

Learners' focus (group) interview:

In this focus interview, L1 refers to a learner whose home language is English, L2 refers to a learner whose home language is Afrikaans, L3 refers to a learner whose home language is IsiZulu/IsiXhosa and J.J refers to the interviewer.

Statements	Commentary
J.J: Good morning, in this session I want to ask you what you think about Physics lessons- ok?	J.J. sets the scene and checks that the interviewees understand what is coming.
J.J: What language would you prefer to use during Physics lessons?	Long pause…
J.J: The language which you think would make it easier to understand Physics?	J.J. rephrases the question
L1, L2, L3: Oh! Oh! Oh! English Sir!	Almost in unison, but L3 looks not sure
J.J: L3, what do you say?	J.J. encourages by nodding
L3: Sir… but you can teach me in IsiZulu or translate certain terms when I don't understand.	The learner's head is slightly tilted and almost in a shaking voice.
J.J: Ok, alright!	J.J. nodding again to ret assure L3.
J.J: Fine guys, what are some of the difficulties that you face during Physics lessons?	… No response
J.J: I mean what are some of the challenges you meet or encounter during Physics lessons?	J.J. rephrases his question to encourage the interviewees to answer?
L1: Oh! To come up with the correct equation from a given problem or story and hmm! Identifying the correct formula to use?	L1 looks at others maybe for support.
J.J: Ok, what else?	J.J nodding again to rest assure L1 and encourages others to speak.
L3: Yah! Me sir…I have a problem with big words used in Physics.	L3 almost in an apologetic voice.
L2: Sir, I don't have a lot of problems with the big words used in Physics………………………………I don't understand the Mathematics involved.	Long pause after the first sentence.
L1, Yes, Sir! Some words are not popular ones, I mean common sir.	L1 with a frown after a long pause.

J.J: I see, alright… Then how do you intend to overcome these difficulties?	J.J in an almost a worried voice!
L3: What Sir?	L3 Looking confused
J.J: I mean what should be done to minimize or reduce these problems.	J.J. rephrases the question to trigger responses from the interviewees
L2: I think we should ask a lot of questions and should give us lot of homework.	L2 with a smile
L1: I think you should give us a test immediately after each topic… when we still remember. Right guys!	L3 looking around for support.
J.J: What do you think L3?	After realizing that L3 was not participating for some time.
L3: Nobody can help me with my homework in my family, no one!	L3 With the sad look on his face.
J.J: …Uh! So far so good guys. Then what do you think your Physics educator should do to help you understand Physics better – guys?	J.J throwing his hands apart and eyes moving from one interviewee to another.
L3: …I think Sir you should not use hard words in test Sir!	L3 with a frown
L2: Sir…I think you should give us a test that is similar to what we have done in class sir… not something different … we get confused.	L2 started with a smile and ends with a frown.
L1: Sir… I think you should explain to me again words like velocity and speed, acceleration and deceleration and distance and displacement…they confuse me Sir!	L1 sounding frustrated
J.J: Thank you very much people	J.J nodding with a sound of relief.

APPENDIX I: CLASS TASK ON MECHANICS

IXOPO HIGH SCHOOL **MECHANICS**

GRADE: 10 **SEPT 2006**

DURATION: 1 HOUR **MARKS: 40**

PHYSICAL SCIENCES TASKS

EXAMINER: **Mr. Malunguza**

MODERATOR: **Mr. Nero**

INSTRUCTIONS TO LEARNERS:

1. This task consist of 4 activities, answer all the activities.
2. Number your answers exactly as the questions are numbered.
3. The marks allocated to each question give an indication of the detail required.
4. Write neatly and clearly.
5. Show all working.
6. Non-programmable calculators may be used.
7. A data sheet is attached for your use.
8. Appropriate mathematical instruments may be used.
9. Marks may be forfeited if instructions are not followed.

<u>SECTION A</u>

<u>Task 1: Multiple Choice Questions</u> **Recommended Time: 14 min**

Write down the number and the correct letter only, e.g. 1.8 D:

1.1 The resultant of two forces acting at a point is maximum when the angle is
A. 0^0
B. 45^0
C. 60^0
D. 90^0
E. 180^0

1.2 The following diagram represents 3 displacements:
$\vec{x_1}$, $\vec{x_2}$ and $\vec{x_3}$

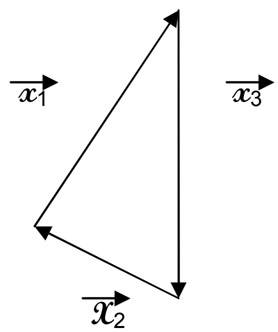


Fig:1.1

Which vector equation is correct?

A. $\vec{x_1} = \vec{x_2} + \vec{x_3}$

B. $\vec{x_1} + \vec{x_2} + \vec{x_3} = 0$

C. $\vec{x_1} + \vec{x_2} = \vec{x_3}$

D. $\overrightarrow{(x_1)^2} = \overrightarrow{(x_2)^2} + \overrightarrow{(x_3)^2}$

E. $\vec{x_3} = \vec{x_2} + \vec{x_1}$

1.3 Which of the following groups are all vectors:
A. Force, weight, velocity and displacement
B. Time, mass, energy and force
C. Mass, weight, velocity and energy
D. Speed, weight, mass and time
E. Time, mass, displacement and momentum

1.4 An aeroplane flies 1000 km in the direction of 180^0 and 750 km in the direction of 360^0. Its resultant displacement is
A. 750 km 180^0
B. 1000 km 180^0
C. 1500 km 180^0

D. 250 km 180^0
E. 1750 km 360^0

1.5 A man walks 4km in the direction 60^0 and then changes direction to 150^0 and walks further 3km. The man's resultant displacement is
A. 7 km 60^0
B. 4 km 150^0
C. 3 km 210^0
D. 5 km 97^0
E. 6 km 90^0

1.6 The resultant of two forces acting at point is minimum when the angle between the forces is

A. 45^0
B. 60^0
C. 90^0
D. 180^0
E. 0^0

1.7 The mass of a 10 kg hangs on the beam as shown in the sketch

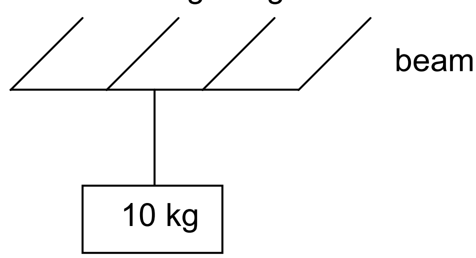


Fig: 1.2

The tension in the rope is:
A. 0 N
B. 10 N
C. 40 N
D. 80 N
E. 100 N

(3 X 7)

SECTION B
Answer all questions in this section

Task 2 **Recommended time: 28 min**

2.1
(a) Distinguish between a vector and scalar. (2)

(b) What can be determined from the following vector?

A ————————————→ (4)

(c) An aeroplane alternately flies 300 km , 400 km and then 200 km in the direction of 60^0 , 130^0 and 270^0. Determine its resultant displacement. (4)

2.2
The winning woman in comrade marathon “up run” completes the 90 km from Durban to Pietermaritzburg in exactly six hours. Calculate her average speed

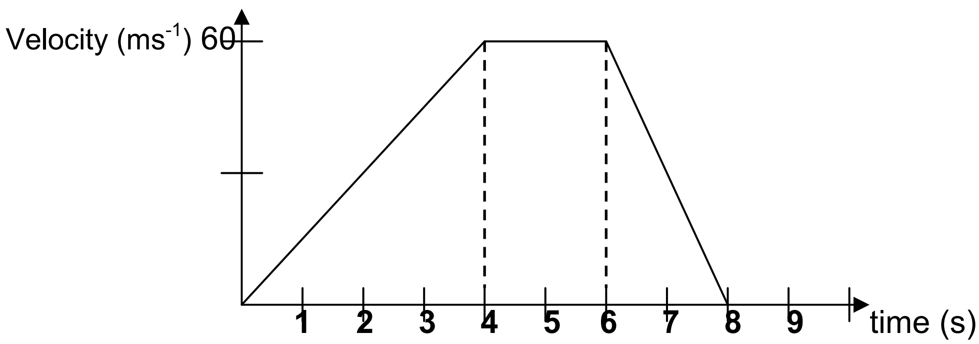
a. in km/h (3)
b. m/s (2)

2.3
In which parts of the run described in question 2.2 is the runner’s instantaneous likely to be:

(a) less than her average velocity? (2)
(b) greater than her average velocity? (2)

Task 3 **Recommended Time: 18 min**

The following graph represents the relationship between velocity and time of a moving object. Use the graph to answer the following questions:



3.1 During which time interval did the object experience no acceleration? (2) 3.2
At which time interval did the object experience a velocity of 30 ms^{-1}? (2)
3.3 How long does the object take to come to rest? (2)
3.4 Calculate the deceleration of the object between 6^{th} and 8^{th} seconds of its movement. (5)
3.5 Calculate total displacement of the object. (7)
3.6 Calculate the average velocity of the object during the 8 seconds. (2)

&&&&&&&&&&&&&&&&&&&&GOOD LUCK&&&&&&&&&&&&&&&&&&&&

APPENDIX J: BLOOM'S TAXONOMY

Category	Example and Key Words
Knowledge: Recall data or information.	**Examples**: Recite a policy. Quote prices from memory to a customer. Knows the safety rules. **Key Words**: defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states.
Comprehension: Understand the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.	**Examples**: Rewrites the principles of test writing. Explain in one'own words the steps for performing a complex task. Translates an equation into a computer spreadsheet. **Key Words**: comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, gives **Examples**, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates.
Application: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.	**Examples**: Use a manual to calculate an employee's vacation time. Apply laws of statistics to evaluate the reliability of a written test. **Key Words**: applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.
Analysis: Separates material or concepts into component parts so that its organizational structure may be	**Examples**: Troubleshoot a piece of equipment by using logical deduction. Recognize logical fallacies in reasoning. Gathers information from a department and selects the required tasks for

understood. Distinguishes between facts and inferences.	training. **Key Words**: analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.
Synthesis: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.	**Examples**: Write a company operations or process manual. Design a machine to perform a specific task. Integrates training from several sources to solve a problem. Revises and process to improve the outcome. **Key Words**: categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes.
Evaluation: Make judgments about the value of ideas or materials.	**Examples**: Select the most effective solution. Hire the most qualified candidate. Explain and justify a new budget. **Key Words**: appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports

APPENDIX K: QUESTIONNAIRE REGARDING PROBLEM SOLVING STRATEGIES

ANSWER KEYS: TICK THE APPROPRIATE BOX.
NO - No I didn't do this.
MAYBE - I may have done this.
YES - Yes, I did do this.

1. BEFORE YOU BEGAN TO SOLVE PROBLEMS – WHAT DID YOU DO?	**NO**	**MAYBE**	**YES**
1. I read the problem more than once.			
2. I thought to myself: Do I understand what the problem is asking me?			
3. I tried to put the problem into my own words.			
4. I tried to remember if I had worked a problem like this before.			
5. I thought about what information I needed to solve this problem.			
6. I asked myself: Is there information in this problem I don't need?			
2. AS YOU WORKED ON THIS PROBLEM – WHAT DID YOU DO?	**NO**	**MAYBE**	**YES**
7. I thought about all the steps as I worked on the problem.			
8. I kept looking back at the problem after I did a step.			
9. I had to stop and rethink a step I had already done.			
10. I checked my work step by step as I worked on the problem.			
11. I did something wrong and had to redo step/s.			
3. AFTER YOU FINISHED WORKING ON THE PROBLEM – WHAT DID YOU DO?	**NO**	**MAYBE**	**YES**
12. I looked back to see if I did the correct procedures.			
13. I checked to see if my calculations were correct.			
14. I went back at the problem to see if my answer made sense.			
15. I looked back at the problem to see if my answer made sense.			
16. I thought about a different way to solve the problem.			
4. DID YOU USE ANY OF THE FOLLOWING WAYS OF WORKING?	**NO**	**MAYBE**	**YES**
17. I drew a picture to help me understand the problem.			
18. I "guessed and checked".			
19. I picked out the operations I needed to do this problem.			
20. I felt confused and could not decide what to do.			
21. I wrote down important information.			

Adapted from: Breen, C. J. et al (1992). *Mathematics teachers*