EFFECTIVE TEACHING OF ENERGY IN MECHANICS

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ABSTRACT

Science learners come to class with pre-instructional ideas that may influence the acquisition of science concepts. A basic assumption of the constructivist learning theory is that these pre-instructional ideas should be taken into account in constructing learners' conceptual frameworks in science classes. Several conceptual change strategies have been studied in order to alter unscientific (called alternative) conceptions towards the scientifically accepted conceptions. The challenging task of the science educator is to select appropriate teaching strategies and techniques that will enhance learning.

The study reported here investigates the effectiveness of an activity-based approach in the teaching of energy in Grade 10 Physical Sciences. The approach takes into account the prior beliefs adhered to by learners. A learning sequence was developed, presenting a variety of problems in such a way and order that learners' conceptions could progressively be changed from their alternative conceptions to the scientific conceptions. The sequence progressed from contextual to conceptual to formal activities. Co-operative learning, inquiry, verbalisation and analogous reasoning techniques were used to guide learners in the acquisition of the scientific concepts. The approach is based on the assertion that learners' scientific knowledge and understanding are socially constructed through talk, activity and interaction around meaningful problems and tools. Consequently, this activity-based strategy is in line with contemporary learner-centred approaches as manifested in the National Curriculum Statement for FET physical sciences.

The research population consisted of fifty five (55) physical science learners enrolled at the Hans Kekana High School in a rural village, Majaneng, in the Gauteng Province. The questionnaire that served as pre- and post-test probed into learners' alternative conceptions of energy. The effectiveness of the intervention was indicated by the amount of conceptual change accomplished that followed from a calculation of the normalised learning gain.

OPSOMMING

Wetenskap-leerders kom klas toe met voor-onderrigidees wat hul verwerwing van wetenskapkonsepte mag beïnvloed. 'n Basiese aanname van die konstruktivistiese leerteorie is dat hierdie voor-onderrigidees in aanmerking geneem moet word wanneer leerders se konseptuele raamwerke in wetenskapklasse saamgestel word. 'n Aantal konseptuele strategieë is bestudeer ten einde onwetenskaplike (genoem alternatiewe) begrippe van wetenskaplik aanvaarde begrippe te verander. Die uitdaging vir die wetenskap-opvoeder is om toepaslike onderrigstrategieë en tegnieke te kies wat leer sal versterk.

Die studie wat hier gerapporteer word, ondersoek die doeltreffendheid van 'n aktiwiteitgebaseerde benadering in die onderrig van energie in Graad 10 Natuurwetenskappe. Dié benadering neem die vooropgestelde oortuigings wat leerders huldig, in aanmerking. 'n Volgorde vir leer is ontwerp wat 'n verskeidenheid probleme op so 'n wyse aanbied dat leerders se oortuigings progressief verander van hul alternatiewe begrippe na die wetenskaplike begrippe. Dié volgorde het gevorder van kontekstuele tot konseptuele tot formele aktiwiteite. Samewerkende leer, verbalisering en analoogredenasietegnieke is gebruik om leerders te lei in die aanvaarding van wetenskaplike begrippe. Die benadering is gebaseer op die aanname dat leerders se wetenskaplike kennis en verstaan sosiaal gekonstrueer word deur gesprek, aktiwiteite en interaksie rondom betekenisvolle probleme en werktuie. Gevolglik is hierdie aktiwiteitsgebaseerde strategie in lyn met hedendaagse leerdergesentreerde benaderings soos blyk uit die Nasionale Kurrikulumstelling vir FET natuurwetenskappe.

Die navorsingspopulasie het uit vyf en vyftig (55) natuurwetenskapleerders bestaan wat ingeskryf is by die Hans Kekana Hoërskool in die landelike dorpie Majaneng, in die Gauteng Provinsie. Die vraelys wat as voor- en na-toets gedien het, het die leerders se alternatiewe begrip van energie ondersoek. Die doeltreffendheid van die intervensie is aangedui deur die hoeveelheid konseptuele verandering wat gevolg het op 'n berekening van die genormaliseerde leerwins.

TABLE OF CONTENTS

Chapter 3

Contemporary teaching strategies

Chapter 4

Research methodology

Chapter 5

Results and discussion of results

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

OVERVIEW

1.1 PROBLEM ANALYSIS AND MOTIVATION FOR THIS STUDY

During the past decades, a great deal of research has been devoted to learners' alternative frameworks (Driver & Easley, 1978) vis-à-vis physical phenomena. Today, it is generally accepted that learners' pre-instructional knowledge plays a crucial role in the acquisition of science concepts. Researchers like Nussbaum and Norvick (1982b) and Robert (2000) have shown that learners' alternative frameworks that differ from scientific conceptions interfere with their learning of science. This is consistent with the constructivist notion that the internalisation (selective perception and interpretation) of new information and ideas by a person is a function of his existing conceptual framework (Ausbel, 1968). The study of learners' frameworks is based upon the assumption that if the learners' conceptions were to grow into more sophisticated understanding of physics, educators must first establish what conceptions they have, and then teach them accordingly.

In the realm of energy, a large number of studies over the past three decades (e.g. Duit 1981, Bliss & Ogborn, 1985, Trumper, 1991, Pintó *et al.*, 2004) have yielded valuable information about how learners understand this abstract and difficult-to-grasp concept. Watts (1983) classified learners' alternative conceptions of energy into the following seven categories:

1) Anthropocentric: Energy is associated with human beings.
2) Depository: Some objects have energy and expend it.
3) Ingredient: Energy is a dormant ingredient within objects, released by a trigger.
4) Activity: Energy is an obvious activity.
5) Product: Energy is a by-product of a situation.
6) Functional: Energy is seen as a very general kind of fuel associated with making life comfortable.

7) Flow transfer: Energy is seen as a type of fluid transformed in some processes.

Frameworks number 1, 2, and 5 are the most pervasive alternative frameworks (Watts, 1983, Trumper, 1990).

The first research question of the study reported here is to determine whether the Grade 10 learners of a South African school hold these alternative frameworks. The concept of energy is not new to Grade 10 learners, because Energy and Change is one of the four learning areas taught in the General Education and Training (GET) band (grades 4 to 9) (Department of Education, 2003a). The study of mechanics in the Further Education and Training (FET) band (grades 10 – 12) is based on concepts formed in the Learning Area Energy and Change. This emphasizes the importance to determine and remedy Grade 10 learners' alternative conceptions regarding the concept of energy.

All alternative conceptions are not unacceptable and in conflict with the accepted scientific concepts (Gilbert & Watts, 1983). An example is the perception that energy is associated with human beings (framework 1). This is a limited idea that should be expanded to an understanding that all objects have energy that can be transformed or transferred. In this case, we talk about an evolutionary change that involves the facilitation of extension in richness and precision of meaning for learners' conceptions. This is one of the teaching strategies aimed to accomplish conceptual change in the science classroom reviewed by Scott *et al.* (1992). Ausbel (1968) described a process of meaningful learning that results in the sub-sumption of new knowledge. In this process, the new knowledge interacts with existing concepts and is assimilated into them, altering the form of both the anchoring concepts and the newly assimilated knowledge (Novak, 1978). Vosniadou and Ioannides (1998) point out the value of relating conceptual change to social, cultural and situational factors.

Alternative conceptions are extremely resistant to change (Scott *et al.,* 1992). Learning and teaching science involves more than just substituting everyday knowledge with scientific knowledge (Hewson & Thornley, 1989; Crespo, 2004). Although numerous perspectives about conceptual change have been proposed, the one initiated by Posner *et al.* (1982) is amongst the most influential models, and has gained support from research literature and teaching practice (e.g. Hewson & Thorley, 1989). According to Posner *et al.* (1982), learners would not abandon their tenaciously held ideas and beliefs and accept new ones unless they were dissatisfied with the former or found the latter intelligible, plausible and fruitful.

Science education researchers (e.g. Hake, 1998; Kabapinar, 2004) found that interactive teaching strategies such as inquiry and problem-based approaches result in higher gains in knowledge and understanding of scientific concepts. In learner-centred science curricula such as the National Curriculum Statements of South Africa, science learning is active and constructive, involving inquiry and hands-on activities. The purpose of such activities is to develop critical thinking and problem-solving skills by posing and investigating relevant questions (Taraban *et al.*, 2007). The use of a wide range of learner-centred activities improve both attitudes towards science and the learning of science (Ramsden, 1994), which include factual recall as well as knowledge of process skills (Taraban *et al.*, 2007). Research has also established that disadvantaged (academically or economically or both) learners specifically benefit from activity-based programmes (Donnellan & Roberts, 1985). Consequently, an activity-based intervention was chosen for the empirical study reported here. A variety of learner-centred instructional strategies were implemented in the intervention to provide different contexts for learning. The second research question focussed on the effectiveness of the designed activity-based learning sequence to accomplish conceptual change regarding the group of Grade 10 learners' perceptions of energy.

1.2 AIM OF THE STUDY

The research aim of the study reported here was to investigate the effectiveness of an activity-based learning sequence to remedy Grade 10 learners' alternative conceptions of energy in mechanics.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study were twofold, namely to:

(1) Determine the alternative conceptions of Grade 10 learners about the concept of energy and identify them in terms of the classification of Watts (1983); and

(2) compile and test an instructional sequence compromising of activity-based lessons in mechanics to accomplish conceptual change.

1.4 HYPOTHESIS

Grade 10 learners who participate in activity-based learning of energy demonstrate a larger learning gain compared to learning gainsof those who participate in traditional instruction.

1.5 RESEARCH METHOD

1.5.1 Literature study

Study material was obtained in the library and from the Internet. Recent publications on the subject in scientific and educational journals (locally and abroad) were searched with the aid of search engines available in the library. The following key words were used: alternative conceptions, energy, conceptual change, problem-based, teaching, constructivism.

The literature study was conducted to gain an in-depth knowledge about learners' alternative conceptions on energy in mechanics, as well as constructivist teaching strategies that can be used to remedy them. During the course of this study, problem areas were identified to be addressed in the questionnaire and the intervention that formed part of the empirical study.

1.5.2 Empirical study

The method to acquire data for the empirical study was as follows:
First, a pre-test (questionnaire) was given to the Grade 10 learners for diagnostic purposes, i.e. to determine their alternative conceptions. The intervention strategies based on activity-based learning comprised of three lessons, each taking fifty minutes. A variety of activities were chosen and ordered so that learners' conceptions could

progressively be changed from their alternative conceptions to scientific ones. The succession of activities and discussions enhanced progress from contextual to conceptual to formal understanding of the concepts. A post-test was (same questionaire as pre-test) was done afterwards to verify the success of the intervention. The results were analysed and normalised learning gains calculated to indicate the effectiveness of the intervention. The obtained learning gain was compared with those found in literature for contemporary and traditional instruction.

1.5.3 Population

The empirical study focused on a group of fifty-five (55) science learners. The learners were in Grade 10 and were enrolled at Hans Kekana High School in Majaneng Village north of Pretoria (Tshwane) at Hammanskraal. Most of the learners' parents work in Pretoria (Tshwane) and they are from different socio-economic backgrounds.

1.6 CHAPTER DIVISION

The problem analysis, motivation and research method of the study were outlined in Chapter 1. In Chapter 2 a literature review on alternative conceptions regarding energy is reviewed, followed in Chapter 3 by a discussion of contemporary teaching strategies that can be used to promote learning of the scientific concepts of energy. This literature study serves as framework for the empirical study, of which the research methodology is described in Chapter 4. Chapter 5 gives the results of the empirical study and the discussion thereof. The conclusions and recommendations that emanate from this study are found in Chapter 6.

CHAPTER 2

LITERATURE REVIEW ON ALTERNATIVE CONCEPTIONS REGARDING ENERGY

2.1 INTRODUCTION

Since early childhood learners experience the natural world and formulate intuitive ideas that often differ from accepted scientific ideas (Shuell, 1987). No matter how non-scientific these ideas may be, learners will attempt to fit what is being taught into their existing framework. The starting point of any teaching sequence should therefore take into account their intuitive ideas (Stavy *et al.,* 1980). In science the intuitive ideas that differ from the scientifically accepted meanings are called alternative conceptions.

This chapter reports on a literature study of alternative conceptions regarding the concepts of energy (section 2.2) and how such alternative conceptions can originate (section 2.3). The literature study formed the basis of the compilation of the questionnaire used in the empirical study (Chapter 4) and the interpretation of the results (Chapter 5).

2.2 ALTERNATIVE CONCEPTIONS ABOUT ENERGY

2.2.1 General perceptions of energy

Learners' understanding of the concept of energy before and even after traditional instruction often differs from its scientific meaning (Brown, 1977). Some learners believe energy is associated only with humans or movement, others that energy is a fuel-like quantity that is used up, or that energy makes things happen and is expended in the process. Rarely does a learner think energy is measurable and quantifiable. Learners of all ages can hold these ideas of energy. Watts (1983) categorised the most popular and persistent alternative conceptions about the concept of energy as follows:

- 'Human-centred' energy. Many of the descriptions that learners give when describing energy are anthropocentric and anthropomorphic. This means that the descriptions associate energy mainly with human beings, or treat objects as if they had human attributes. This idea is found amongst all ages and although advanced learners adopt the traditional 'third person passive' register of physics, they find it difficult to maintain. Considering the example of a man pushing a box up a hill, a typical response would centre on the person as having energy, but certainly not the box.

- A 'depository model' of energy. This is a model of energy that Clement(1987) calls a 'source of force' model. From this point of view learners see some objects as having energy (and being rechargeable), some as needing energy and simply expending when they get it and yet others as neutral and whose activities are somehow normal or natural. Energy is then perceived as a casual agent, a source of activity based or stored within certain objects.

- Energy as an ingredient. Solomon (1980) noted this feature when learners talk about food. Learners believe that energy is not stored in food, but only provides you with energy when you eat it. They regard energy as an ingredient. In this framework energy is not necessarily a casual agent but a reactive one.

- Energy is functional. In many instances energy is seen as a very general kind of fuel, with some limitations. Firstly, energy is more or less restricted to technical appliances and secondly it is not essential to all processes but is mainly associated with those things that make life more comfortable. As Duit (1981) says: "for a life without technical aids it seems no energy would be needed". This framework carries a suggestion of why energy might be an important concept (but without its general applicability). For these learners energy is deliberately contrived to be useful.

- Energy is a product. In contrast with the previous notions this alternative conception carries the suggestion that energy is not an ingredient or a process. In some sense it is rather like a waste product such as smoke, sweat or exhaust fumes. As with other alternative conceptions, energy is treated as a relatively short-lived product that is generated, is active and then disappears. Energy is non-conserved.

- Energy is an obvious activity. To many learners an outward overt display of activity is the sole means of identifying energy. Moreover, the activities themselves are called energy. Movement of any kind is widely given as a reason for energy being involved. Energy is perceived as the movement itself.

- A flow-transfer model of energy. Warren (1982) points out that the idea that energy is a fluid is both an implicit suggestion behind the way in which the concept is commonly taught in schools. In this way energy is seen as being 'put in', 'given' , 'transported' or 'conducted'. According to Arons (1965), energy is not a substance, fluid, paint or fuel that is smeared on bodies or rubbed off from one to another.

The above listed learners' ideas about what energy is. In the next section (2.2.2) learners' alternative conceptions regarding energy in mechanics are compared with the scientific conceptions.

2.2.2 Conceptions about energy in the context of mechanics

2.2.2.1 Scientific conceptions of energy

Although it is very difficult to define energy, scientists know that in every change that occurs in nature, no matter how small, energy is involved. In mechanics, energy is often defined as the ability to do work (Brookes *et al.,* 2005). It is, however, important to know that when work is done by a source of energy such as a fuel, a part of the energy in the source is transferred to another form, place or object, which is usually less usable (Eisen *et al.,* 1987). However, the total amount of energy of a system remains constant (Brookes *et al.*, 2005), because energy cannot be created or destroyed. This is the principle of conservation of energy.

2.2.2.2 Alternative conceptions regarding energy in mechanics

Literature (Kuhn,1983; Edwards *et al.*, 1987;Driver *et al.,* 1989; Gilbert & Watts, 1983; Brown, 1977; Brookes *et al.,* 2005;Roberts, 2000; Clement, 1987; Driver, 1989; Hubisz, 2003). reveals the following alternative conceptions and conceptual problems regarding the concept of energy in mechanics. (The alternative conceptions or conceptual problem is/are underlined.)

- An object at rest has no energy. Scientifically, an object at rest could have potential energy. It definitely has internal energy (at molecular and atomic levels).

- Learners experience problems with understanding potential energy (Kuhn, 1983). In science, potential energy is a form of energy due to gravitational position, such as resting on the top of a hill. Potential energy can also be found in compressed springs, stretched out rubber bands, or other materials that involve compression and stretching. Potential energy can also be transformed in ways that do not involve motion directly. Energy stored in molecules is usually released in the form of heat or light. Food can be thought of as a type of potential energy since, once digested, it undergoes a series of chemical changes that convert some of this potential energy into heat or even mechanical energy when the body moves.

- Gravitational potential energy depends only on the height of an object above a chosen reference level (Edwards *et al.,* 1987). The gravitational potential energy of an object also depends on the gravitational acceleration and the mass of the object.

- Scientific and everyday life meaning of the concept of work differ. In mechanics, work is defined as force exerted over a distance in the direction of motion. From the non-scientific point of view, work is synonymous with labour. It is hard to convince someone that more work is probably being done by playing for one hour than by studying for an hour. Since distance is related to work (which is energy expenditure) for example, playing soccer would burn a lot more calories than studying would (Driver *et al.,* 1989).

- An object moving at a constant velocity requires a force in the direction of motion. The force of a moving body gradually weakens, resulting in a decrease in velocity until the object stops (in the absence of force. (Gilbert & Watts, 1983). Scientifically, the resultant force on an object moving at constant velocity is zero. The velocity of a moving object will decrease when subjected to a force acting in the direction opposite to the motion. Although the resultant force acting on a moving object may be zero, the object always has energy.

- Energy is lost in many energy transformations. Energy can completely change from one form to another without energy loss. According to the law of conservation of energy, energy changes forms even if the forms were not readily detectable. In real life, a part of energy becomes heat (Brown, 1977). The total amount of energy in a system always remains constant (Brookes *et al.,* 2005).

- The term 'conservation of energy' can be confusing
  Learners can ask: "If energy is conserved, why are we running out of it?" The reason is that energy is converted to forms that are not humanly useful (heat for example).

2.3 ORIGIN OF ALTERNATIVE CONCEPTIONS

Alternative conceptions can haunt learners' science learning until they feel confronted and overcome. The discussion in the paragraph below reflects that alternative conceptions can originate from everyday experience (paragraph 2.3.1) terminology (paragraph 2.3.2), teaching (paragraph 2.3.3) and textbooks (2.3.4).

Chi *et al.* (1994) proposed an explanation for why some scientific concepts cannot be changed easily. The scientific meaning of some concepts belong to a different ontological category than learners' intuitive meanings. For example, learners may conceive some basic science concepts as belonging to the ontological category of material substance, while scientists consider their entities belonging to the ontological category of constraint-based events.

2.3.1 Everyday experiences

Preconceived notions or preconceptions of the natural world are popular conceptions rooted in everyday experiences. For example, learners observing a moving object slowing down (decelerating) mistakenly believe that the force responsible for the motion is getting used up (Roberts, 2000). Such alternative conceptions are very common because they are rooted in the most common activity of young children, namely unstructured play. When children are exploring their surroundings, they will naturally attempt to explain some of the phenomena they encounter in their own terms and share their explanations. When children arrive at an incorrect assumption, this preconception is also an alternative conception.

2.3.2 Terminology

Vernacular alternative conceptions can be distinguished from factual alternative conceptions (Clement, 1987). Vernacular alternative conceptions arise from the use of words that mean one thing in everyday life and another in the scientific context. For example, the term work in the physics classroom refers to the result of multiplying a force measured in Newton by the straight-line distance moved in meters in the direction of the force. The introduction of the definition of work in a physics classroom consequently presents many challenges to the teacher (Clement, 1987). The power (change in energy per unit time) concept is a similar example of a concept with different meaning in and out of the science classroom. Learners, however, perceive the terms energy and power as the same thing because in their everyday usage these two concepts are regarded as the same (Driver, 1989)

These examples illustrate that a mismatch may occur between the scientific meaning of terms and everyday usage. These mismatches should be attended to before effective learning could take place (Clement, 1987).

Science education research (Driver *et al.*, 1989) has revealed that learners think energy is a thing. This is a fuzzy notion, probably originating from the way that we talk about Newton-meters or joules.

2.3.3 Teaching

Conceptual misunderstanding arises when students are taught scientific information in a manner that does not encourage them to settle any cognitive disequilibrium. In order to deal with their confusion, students construct a weak understanding and consequently are very insecure about constructed concepts. An example of this is the very commonly found "Force as a property of an object" misconception (Brown, 1977). Forces are dependent upon and related to objects but are not properties of them, yet students continually perceive that forces are intrinsic to the objects (Roberts, 2000).

Alternative conceptions can result from deficiencies of curricula and methodologies that do not provide the students with suitable experiences to assimilate the new concepts. It is rare that an alternative conception results from lack of reasoning abilities that are necessary to assimilate the new concept (Brown 1977).

2.3.4 Textbook

Hubisz (2003) and his committee investigated physical science textbooks and found that they fail to present what science is all about. The committee was particularly concerned with scientific accuracy and with good reasons. Mass and weight were often confused in textbooks. Isaac Newton's first law in some of the textbooks was often incorrectly stated. Although the third law was correctly stated, examples illustrating it were wrong.

According to Hubisz and his committee (2003), many errors in textbooks involve sloppy use of language. For example, the terms speed, velocity and acceleration are often confused. Writers often refer to gravitational acceleration as gravity or the force of gravity. In some texts that were investigated by Hubisz and his committee, one text reported that an object is a force rather than that it exerts a force. Hubisz (2003) reports that alternative conceptions such as that heat is a fluid occur in most textbooks. Such errors in textbooks can create or enhance alternative conceptions.

2.3.5 Summary

Energy is a key scientific concept that is introduced in primary school science, i.e. early in learners' careers. It permeates science learning from this stage. There are many alternative conceptions that trouble even high school physics learners. Sources of alternative conceptions include everyday experiences, vernacular terminology, ineffective teaching and textbook errors. Language usage, everyday experiences, analogies and metaphors can cause learners difficulty in forming acceptable understanding of physics concepts, theories and laws. Educators should learn to discover their learners' alternative conceptions and apply methods and strategies to confront them. The next chapter discusses contemporary teaching strategies that can be used to address learners' alternative conceptions on energy in order to accomplish conceptual change.

CHAPTER 3

CONTEMPORARY TEACHING STRATEGIES TO PROMOTE LEARNING

3.1 INTRODUCTION

Over the last decades an active research programme has been established in the area of learners' conceptual understanding in Science (Scott *et al.,* 1992). Learning is seen in terms of conceptual development or change (see paragraph 3.2) rather than piecemeal accretion of new information (Scott *et al.,* 1992). Various models of learning based upon this viewpoint have been proposed, some deriving from epistemological literatures (Posner *et al.,* 1982), and others from cognitive psychology (Osborne *et al.,* 1983). All of this work has strong implications for classroom practice.

The importance of learners' prior knowledge for the acquisition of new knowledge and the need to sequence instruction to build upon the learner's existing concepts and propositions has been established (Novak, 2004: 23). Approaches to teaching that acknowledge learners' alternative conceptions have been researched, developed and tested (refer to paragraph 3.3). These teaching approaches involve a range of different pedagogical strategies, drawing upon various aspects of the underlying theory of constructivism (Osborne *et al.,* 1983). The challenging task of the educator is to select the appropriate teaching strategy and techniques (paragraph 3.4) that will enhance learning (Trowbridge *et al.,* 2004: 149).

3.2 CONSTRUCTIVISM

3.2.1 A constructivist approach to teaching

A constructivist approach to teaching assumes the existence of learners' conceptual schemata and the active application of these in responding to and making sense of new situations (Trumper, 1990). Some recognised features of constructivism are (Collins, 2002):

- Learning is the interaction of ideas and processes.
- New knowledge is built on prior knowledge.
- Learning is enhanced when situated in contexts that learners find familiar and meaningful.
- Complex problems that have multiple solutions enhance learning.
- Learning is augmented when learners engage in discussions of the ideas and processes involved.

Applied to science education, the constructivist view supports teachers who are concerned with the investigation of learners' ideas and who develop ways that incorporate these viewpoints within a learning-teaching dialogue (Trumper, 1990). An assumption of the constructivist approach is that the learner is active and purposeful during the learning process. He or she is actively involved in bringing prior knowledge to bear in order to construct meanings in new situations. In order to deal with learners' prior knowledge, the beliefs they adhere to should first be identified (Trumper, 1990).

Science teachers are well aware that even when they explain ideas slowly, carefully , and clearly, learners often fail to grasp the intended meaning (Driver, 1997). Understanding how learners learn and why they often struggle to grasp our intended meaning is the foundation of informed teaching. To achieve robust long term understanding, multiple connections must be erected and grounded in experience , but unfortunately these links cannot simply be given to learners (Driver,1997).

Fundamental to our understanding of learning is that learners must be mentally active, selectively taking in and attending to information, and connecting and comparing it to prior knowledge in an attempt to make sense of what it is being received (Driver, 1997). However, in attempting to make sense of instruction, learners often interpret and sometimes modify incoming stimuli so that it fits (i.e. connects) to what they already believe on. Consequently, learners' prior knowledge that is at odds with intended learning can be incredibly resistant to change (Driver, 1997).

Driver (1997) argued that some of the more complicated learning we have to do in life, and a lot of science is like this, involves not adding new information to what we already know, but changing the way we think about the information we already have. It means developing new ways of seeing things.

3.2.2 Conceptual change theory

It has been proven that learners come to class with personally constructed knowledge and ideas about the world. This forms the basis of the theory of constructivism. Learners' alternative perceptions stand in the way of the teaching and learning process (Driver *et al.,* 1985:3). It becomes difficult to change learners' conception about their ideas before engaging them in the intended learning experience. This process of changing learners' views is referred to as conceptual change (Scott *et al.*, 1982).

Posner *et al.* (1982:212) assert that there are two distinguishable phases of conceptual change in science. The first is based on ordinary scientific work that is done against the background of central commitments, or paradigms. The second phase of conceptual change occurs when these paradigms require modification. According to Kuhn, this leads to a scientific revolution (Posner et *al.*, 1982: 212).

Too often educators of physics consider their learners to be "clean mental slates" and act accordingly in order to fill their "empty vessels" (Cosgrove, 1985). The problem with this approach is that the vessels are not empty but contain preconceptions. Learning cannot be a passive process of just absorbing knowledge, it includes the modifying and restructuring of ideas to fit into the existing framework (Driver *et al.,* 1985), otherwise learners' naive theories or preconceptions may lead to misconceptions and thus may interfere with the acquisition of scientifically accepted concepts.

Posner *et al.* (1982) proposed a model of conceptual change that involves a series of conditions, namely:

(1) Learners become dissatisfied with existing alternative conceptions because the conceptions appear useless to solve a problem.

(2) A new conception must be intelligible.

(3) A new conception must appear initially plausible.

(4) A new conception should be fruitful, have more explanatory power and is useful to solve problems.

Science educators (e.g., Hewson & Thorley, 1989) also suggest that the learners are the ones that should judge whether these conditions are being met

Scott *et al.* (1992) review strategies to accomplish conceptual change in the science classroom. Many researchers have claimed that conceptual change occurs through cognitive conflict in what Gilbert and Watts (1983) call a revolutionary change process. However, some alternative conceptions such as the one in which energy is associated with human beings, is not an unacceptable conception conflicting with the accepted scientific concept (Gilbert & Watts 1983). Rather, it is limited, and should be expanded to an understanding that the principle of conservation of energy hold for all objects. In this case we talk about an evolutionary change, which involves the facilitation of extension in richness and precision of meaning for learners' conceptions (Gilbert & Watts 1983). Trumper (1991) successfully implemented this idea.

3.3 CONSTRUCTIVIST TEACHING STRATEGIES

3.3.1 Activity-based learning

In a learner-centred science curriculum, learning science is active and constructive, involving inquiry, hands-on activities as well as minds-on analyses of problem-oriented scenarios (Taraban *et al.*, 2007:961). What a student does is actually more important in determining learning than what the educator does. The greater learners' involvement, the better and more long-lasting their learning (Donnellen & Roberts, 1985). The aim of activity-based learning is to develop critical thinking and problem-solving skills by posing and investigating relevant questions (Taraban *et al.*, 2007:961). The task of the educator as facilitator is to create learning conditions in which learners actively engage in experiments, interpret and explain data and negotiate understandings of their findings with peers. Research has established that disadvantaged (academically or economically or both) learners are especially benefited by activity-based programmes (Donnellan & Roberts, 1985).

In activity-based learning a variety of learner-centred instructional strategies are implemented to teach science (Ramsden, 1994; Taraban *et al.*, 2007). The activities are designed to encourage active learner involvement. Learners are usually organised into collaborative learning groups. The use of a wide range of learning activities improves both motivation and learning of science (Ramsden, 1994). Taraban *et al.* (2007) obtained significant effects for factual recall, knowledge of process skills as well as positive attitudes towards science learning. Different constructivist teaching strategies that can be implemented in activities to accomplish conceptual change are discussed in the following paragraphs (3.3.2 to 3.3.4).

Activity-based learning places particular emphasis on the use of everyday contexts as starting point from which scientific concepts are developed and scientific ideas explored (Ramsden, 1994:7). In this way learning starts from learners' experiences and can be guided towards an understanding of the concepts, methods and structures of physics (Lemmer & Lemmer, 2005). The contextual approach that can be used in activity-based teaching is discussed in paragraph 3.4.

3.3.2 Problem-based activities

The adoption of problem-based learning as a teaching strategy fits in well in contemporary science education (Cashion *et al.*, 2006). Problem-based learning is much more than an instructional strategy. It is adopted by educators to foster not only the development of content knowledge, but also a range of skills and dispositions, such as curiosity, problem-solving, communication and collaborative skills, decision-making, and self-directed learning.

Problem-based learning originated with the work of Dewey (1944), who emphasised the connections amongst doing, thinking, and learning. Learners' scientific knowledge and understandings are socially constructed through talk, activity and interaction around meaningful problems and tools (Bransford *et al.*, 2000). The educator guides and supports learners as they explore problems and define questions that are of interest to them. Learners share the responsibility of thinking and doing.

In the activity-based situation, educators for example give learners contextual problems, conceptual problems and formal problems. Learners spend their time investigating the problem (which will typically involve a set of interrelated problems); the learners will progress from recognition of cues to problem formulation (Engel, 1992:326). The prime educational task of the educator is to ensure that learners make adequate progress towards formulating problems, understanding it better and dealing with it, and establishing before the end of the tutorial how they will organise themselves to pursue learning in preparation for the next tutorial. The educator does this essentially by questioning, probing, encouraging critical reflection, suggesting and challenging in helpful ways when necessary.

3.3.3 Verbalisation

Learners' confrontation of alternative conceptions through verbalisation of understanding is common to many stepwise approaches to teaching and learning strategies for conceptual change (Clement, 1982). If learners can express their difficulties verbally, they are a step closer to overcoming them. This requires an educator to place a greater emphasis on listening in the classroom when having learners verbalise their conceptual understanding. In a constructivist classroom, peers may constructively criticise each other's statements and thus each other's understanding. Learners can refine each other's sample answers to problems. This method will also sharpen the learners' critical thinking skills (Clement, 1987).

It is productive to have learners make verbal statements of understanding to clarify and confront their alternative conceptions. Brown and Clement (1989) emphasise learners' oral and written explanation of their conceptual understanding as a method of isolating their alternative conceptions.

While it is not a common practice within physics education, essay-style questions require learners to review and reorganise their knowledge of the concept at hand in order to explain their understanding of the domain. Setting essay-type assignments asking learners to explain their reasoning can help them to identify their alternative conceptions. In short-answer or essay-type questions, learners cannot hide their conceptions behind formulae. They have to demonstrate their understanding in order to answer the questions (Brown *et al.,* 1989)

3.3.4 Analogical reasoning

Analogies typically involve the presentation of an abstract new concept with a concrete familiar one to help learners to conceptualise it (Lawson, 1993). Analogies can also be used to facilitate the development of conceptual models of newly presented scientific mechanisms or structures by comparing them to something that is familiar to the learners (Iding, 1997).

The use of analogy instruction is to help learners acquire understanding of theoretical concepts or to change their alternative conceptions. For example, Stavy (1991) used analogies to overcome learners' misconceptions about conservation of weight. Analogical reasoning as a tool for helping learners overcome misconceptions is described by different researchers as bridging analogies or chains of analogies (Clement, 1987). Analogical reasoning has been refined for use in the classroom and is encapsulated well in the bridging of analogical strategies. The educator's correct use of bridging analogies can help learners span the conceptual gap between anchor (a mastered) concept and target (misconceived) concepts (Clement, 1987).

The analogical reasoning strategies can involve a series of analogous demonstrations presented sequentially for comparison. An example from Newton's third law is (Brown *et al.*, 1987): A book is lying on a table. Gravity pulls the book towards the centre of the earth (action force). Many learners cannot identify the reaction force when given the action force (weight) of a book lying on a table. The educator may use the analogy of a hand pressing down on a vertical spring where the hand is analogous to the book and the spring is analogous to the table. The concept of reaction force may be clarified by this analogy. The idea is that most learners will understand the book on the table (target concept) after the educator has taught the more comprehensible hand on the spring example (anchor concept). This approach, regardless of the concept to be taught, is heavily laden with the need for concrete examples and demonstration as they help learners to develop visual models of the concepts being studied (Brown *et al.,* 1989).

3.3.5 Inquiry teaching and learning

Inquiry is a process by which children actively investigate their world through questioning and seeking answers to their questions (McBride & Muhammad, 2004). This process is characterised by actions such as probing, searching, exploring and investigating (Trowbridge *et al.,* 2000).

It is possible to describe inquiry issues from different aspects. Kaska and Rannikmaee (2006) emphasize two aspects of inquiry namely, inquiry as means and inquiry as ends. Inquiry as means refers to inquiry as an instructional approach, intended to help learners develop understanding of science content and processes. Inquiry as ends refers to inquiry as instructional outcome to be learned.

According to McBride & Muhammad (2004) inquiry, as a way of learning about the world, should be taught in the context of real life scientific problems involving real life science knowledge. These problems should be relevant to the learners. The learners should initiate the study of these problems as they probe, search, explore and investigate questions of interest to them.

Teaching science by inquiry involves teaching learners the science process skills used by scientists to learn about the world and helping the learners apply these skills when learning science concepts (McBride & Muhammad, 2004). Learners are helped to learn and apply science process skills through conducting problem-centred investigations designed for learning specific science concepts. The teachers help learners generate questions and guide their investigations. This inquiry approach is often referred to as 'guided discovery'. Learners work on their own or in groups to resolve problems, while the teacher give only enough aid to ensure that the learners do not become too frustrated or experience failure (Trowbridge *et al.*, 2004). Teachers guide learners until they discover specific science concepts predetermined by the teachers (McBride & Muhammad, 2004).

Learners develop process skills through carrying out inquiry-based experimental work (Kaska & Rannikmaee, 2006). Trowbridge *et al.* (2004) listed five categories of skills, namely acquisitive, organizational, creative, manipulative and communication skills. The development of learners' skills, which to enhancement of cognitive abilities that is considered important for understanding the real world and formation of attitudes (e.g., curiosity, interest and objectivity).

Pratt and Hackett (1998) suggests that, by learning science by inquiry, learners developed deeper understanding of science concepts and also develop critical thinking skills. However, it is important to stress that learning science concepts by inquiry may be much more time consuming than learning concepts by traditional methods.

The results of documenting science as an inquiry process add to the body of current knowledge. When scientists engage in inquiry they generate knew knowledge. New knowledge is not created in a vacuum. Scientists reason from information that they already have. Newton expressed this idea when he stated that if he had seen further than others, it was because he had stood on the shoulders of giants (Hewitt *et al.*, 1999). Learners can also be taught to utilize inquiry in order to add to the body of science knowledge that is understood. Learners must be taught to reason from what they know and apply this reasoning in order to investigate phenomena observed in the world around them (Schwab, 1962).

It is of utmost importance that learners learn first hand through their own inquiry experiences the processes used by scientists to add to the current body of accepted science knowledge. Upon using science as inquiry strategies, teachers involve learners inquiry–based activities. They do not predetermine science concepts for learners to discover. Teachers involve learners in investigations such as (a) challenging the validity of currently accepted science concepts, (b) going beyond their present understanding of currently accepted science concepts and (c) investigating differing explanations for specific science phenomena (Schwab, 1962).

Towards this end, effective laboratory experiences are highly interactive and make explicit learners' relevant prior knowledge, engender active mental struggling with that prior knowledge and new experiences, and encourage metacognition. Without this learners will rarely create meaning similar to that of the scientific community (Driver, 1997). That is why typical cookbook laboratory activities do not promote, and often hinder, deep conceptual understanding; they do an extremely poor job of making apparent and playing off learners' prior ideas, engendering deep reflection, and promoting understanding of complex content. Such activities mask learners' underlying beliefs and make desired learning outcomes difficult to achieve (Driver, 1997).

Observing learners in an inquiry laboratory is startling different. Instead of learners following descriptive paragraphs during the laboratory, they are provided with a series of challenging questions they attempt to answer through an investigation they designed (Thomas *et al.*, 2006). Biology learners may be asked to design an experiment that demonstrates molecular movement through a membrane or to find observable variations between plant and animals cells by scanning a variety of tissue specimens. In an inquiry–based classroom, learners discuss what procedures will and will not lead them to a valid conclusion; they acknowledge variables that will interfere with their outcome's validity, and learn the importance of maintaining a control sequence to compare to their results (Marbach *et al.,*2000).

Class members are no longer content to sit passively through a lecture or laboratory activity; rather today's learners need to be engulfed in it. Learners who don't become involved in the lesson mentally tune out what is going on and passively await the end of the class with their brains turned off. Lord (1999) describes this as "the couch potato phenomena."

Involving learners in inquiry is much more difficult than simply providing activities for them to do in the classroom (Enger *et al.*,2001). While active learning suggests learners are physically participating in the lesson, inquiry learning requires that they are also mentally participating in it (Enger & Yager, 2001).In fact, academic theorists agree it is more than the mental participation than the physical participation that is the important ingredient to enduring understanding (Wiggins *et al.*, 1998). Learners need to consciously consider the events they are exploring; learners also need to actively examine what they possess and predict the ramifications of intervening with the action (Wiggins & Mctighe, 1998).

3.4 CONTEXTUALISATION AS A DIDACTICAL APPROACH IN PHYSICS EDUCATION

In the science-educational setting, the word "context" can have two different but related usages, the one being knowledge-centred and the other activity-centred (Klassen, 2006). According to Lemmer and Lemmer (2005), the following aspects form part of the context of physics.

1) Philosophical context, which concerns aspects such as the world view of physics;
2) historical context of the development of physics;
3) technological context, which includes the development of measuring techniques, empirical and technological equipment, as well as everyday applications;
4) mathematical context based on the mutual interaction between Mathematics and Physics;
5) relational context in which physics is related to other sciences, such as chemistry and biology as well as social sciences;
6) experiential context that refers to everyday experiences and learners' practical experiences of the world;
7) natural context, i.e. naturally occurring phenomena or events such as lunar eclipses.

The experiential context is used mostly in science education. Contextualisation in the learning process emanated from the learning psychologies of Piaget, Ausubel, Gagne and Vygotsky (Klassen, 2006). The contextual approach is constructivist in nature. It starts from learners' primordial paradigm, subsequently proceeds towards conceptualisation and then to formalism (Lemmer & Lemmer, 2005). New concepts are introduced in a context that is familiar to the learners. Anchoring ideas (Duit, 1981; Clement, 1983) are used to explain the contextual events or phenomena. After conceptual understanding has been assured, the concept is formalised, usually by means of scientific formula and definitions. Contextual, conceptual and formal applications enhance learners' understanding of the concept. In contextualisation, learners are made aware of differences between their paradigm and physics, and guided towards an understanding of the concepts, methods and structures of physics (Lemmer & Lemmer, 2005).

According to Clement (1989), mechanical energy may involve many different things that are familiar to learners. A discussion of the ways things move might be very helpful for learners to visualise mechanical energy. A description of the motions of the human body would a suitable problem for the learners to model. A discussion of simple machines could be used to describe how mechanical energy is transferred from one type of motion to another type of motion.

Duit (1981) proposes the use of semantic anchors to improve understanding of energy conservation. An example of such a semantic anchor is to link energy to learners' everyday experience of fuels, namely that energy is necessary when something is to be set in motion, quickened, lifted, illuminated, and heated, and so on. This means that energy conservation is approached in a step-by-step manner by means of examples and experiments.

3.5 CHOOSING A TEACHING STRATEGY

Shuell (1987) suggests that the educator's task is the non-trivial one of determining which learning tasks are the most appropriate for learners to work on. This poses the central question for science educators: On what basis does the educator make decisions regarding the selection of learning tasks and strategies?

Firstly, the teacher needs to foster a learning environment that will be supportive of conceptual change learning. Such an environment would provide opportunities for discussion and consideration of alternative viewpoints and arguments. A second level of decision-making involves the selection of teaching strategies. Teaching strategies can be seen in terms of overall plans that guide the sequencing of teaching within a particular topic. Finally, consideration must be given to the choice of specific learning tasks (Shuell, 1987). The learning tasks fit into the framework provided by the selected strategy and must address the demands of the particular science domain under consideration.

Shuell (1987) considers four factors that have to be considered in making decisions about appropriate teaching strategies.

- Students' prior conceptions and attitudes: students' prior conceptions across a broad-range science domain have been extensively documented in the literature, and these prior conceptions should be included in teaching.
- The nature of the intended learning outcome: learning outcomes and the logical analysis of those outcomes in science terms have traditionally provided a principle focus for planning teaching.
- An analysis of the intellectual demands involved for learners in developing or changing their conceptions: this analysis focuses upon the nature of the intellectual journey required of the learner in moving from existing conceptions to the intended scientific conceptions.
- A consideration of the possible teaching strategies that might be used in helping pupils from their existing viewpoints towards the scientific view.

Contemporary curriculum standards and learning outcomes are being framed through a constructive lens (Piaget, 1976, 1978; Richardson, 2003).

The South African curriculum is structured as a spiral, or, as some would say, an interactive cycle where concepts are introduced in the primary grades, expanded upon in middle school and refined in high schools. Unfortunately, there are years between these iterations of introduction, expansion and refinement that permit plenty of time for confusion. Schoolyard and backyard interpretations of classroom experience are often not what were intended by the instructor. Many types of misconceptions have originated from diverse sources that may confuse learners. Fortunately, there are many learner-centred approaches to challenge and overcome such problems, some of which are innovative methodologies involving computer-based laboratories (Redish *et al.*, 1997)

Educators must move towards diagnosing learners' alternative conceptions and prescribe appropriate learning activities to remedy them. The educator should allow learners to make their own ideas explicit by talking about them (Kuhn, 1983). Testing of different ideas and competing theories encourage thinking. A variety of activities should be given to learners in order to enable them to recognise all of their alternative conceptions within a new conceptual framework. When observing scientific experiments, learners should be encouraged to consider how models and theories help them to explain what they see. Learners should be given opportunities to use their own new understanding and to make them their own (Brown & Clement, 1989).

To develop learners' conceptions when talking and thinking about the activities, every learner should have the opportunity to make explicit their own conceptions and beliefs. By making their ideas public within a situation of acceptance that there will be a number of alternative conceptions within any group, learners should re-evaluate their ideas and construct understanding closer to those of scientific explanations (Dawson, 1990).

3.6 SUMMARY

Since early childhood, learners have experiences of the natural world and formulate intuitive ideas about concepts, including scientific concepts such as energy (Chapter 2). These intuitive concepts are often very different from scientifically accepted ideas. Learners bring these alternative conceptions into science classroom. According to the constructivist theory, learning involves the construction of meaning that is to a large extent influenced by the learner's existing knowledge.

Science educators must be able to identify and deal with their learners' alternative conceptions in order to accomplish conceptual change. If not treated, learners will encounter problems with the learning of Physical Science. Learner-centred strategies such as analogy reasoning and problem-based learning have yielded good results. A variety of learner-centred strategies should be implemented for successful activity-based learning.

Learner-centred science teaching begins with the background experience and knowledge of learners (Weld, 2002: 78). It recognises that each learner must construct his/her own knowledge and those new concepts and propositions are built upon existing ones (Novak, 2004). Constructing knowledge is a lifelong effortful process requiring significant mental engagement from the learner (Mestre & Cocking, 2002). The constructivist view of learning has two important implications for teaching. The first implication is that the knowledge that learners already possess affects their ability to acquire new knowledge. Secondly, instructional strategies that facilitate the construction of knowledge should be favoured over those that do not.

The next chapter outlines the reserach methodology.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 INTRODUCTION

Learners' underachievement in science has been the subject of major concern in many countries for several years. Among other factors contributing to this problem, two of the most frequently mentioned factors in the extant literature are: (1) learners' alternative conceptions and (2) poor instructional practices (Osborne *et al.,* 1981). The question asked is what instructional strategies could be used to accomplish conceptual change? This question influenced the choice of the researcher (author of this dissertation) in the selection of a combination of a number of instructional strategies in activity-based lessons. The purpose was to address the alternative conceptions that are possibly preventing the Grade 10 learners involved in the study from developing valid scientific conceptions of energy in mechanics. The research design is discussed in this chapter, which outlines the methods and procedures employed in the empirical research.

4.2 POPULATION

The population targeted for the empirical study consisted of fifty-five Grade 10 science learners enrolled at the Hans Kekana High School situated in Majaneng village in the Gauteng Province. Most of the learners are from low socio-economic households. Their mother tongue is Setswana, while English, the language of tuition, is their second language.

4.3 RESEARCH METHOD

In order to pursue the objectives of this study (paragraph 1.3), a quantitative survey was done. A questionnaire was completed to determine the alternative conceptions about the concept of energy held by the Grade 10 science learners (objective 1).

Intervention strategies based on activity-based learning (paragraph 3.3.2) was compiled and presented to the group of Grade 10 learners (objective 2). In order to assess the learners' learning gains due to the intervention, the pre- and post-test method was employed. Prior to the intervention, learners were given the compiled questionnaire as pre-test (see Appendix A). The intervention was an instructional sequence that consisted of three activity-based lessons. Learners' involvement was considered to be the critical aspect of the activities. After the intervention the questionnaire (post-test) was administered to the same group of learners to determine the learning gain and hence the conceptual development attained.

4.3.1 Action research as the methodology for the study of the teaching and learning of science

Leedy and Ormrod (2001:105) characterise action research as a type of applied research that focuses on finding a solution to a local problem in a local setting. By doing action research, educators are researching their own practice of teaching (Feldman *et al.,* 2000). It is an inquiry into their teaching in their classroom. This research is focused on the work of educator researchers, is developmental in nature and improves the educators' practice in order to enhance the learners' learning.

According to Feldman *et al.* (2000), there are several types of action research products, including increased understanding of practice, and improvements in teaching and learning. Teaching and learning are evaluated relative to a specific benchmark or standard.

Knowledge is generated by doing research (Feldman *et al.,* 2000). If action research is to generate knowledge, it must be a legitimate form of research and the results must be seen to be valid. Educators should systematise their enquiries and subject them to critique from within and from outside. The goals of action research are often interpretive rather than explanatory (Feldman et *al., 2000).* Educators need to show that what they have learnt is true in the specific case of the teaching in their classrooms.

Action researchers can evaluate the effectiveness of new instructional methods or materials through outcomes measures, or they can use ongoing formative assessment within the context of the teaching situation (Feldman *et al.*, 2000). Educators get an immediate evaluation of how implementable the suggested improvements are. Some ideas can be rejected out of hand. Other ideas may need to be modified because of large class size, multiple presentations, or the socio economic status of the learners.

According to Feldman *et al.* (2000), action research reduces the time lag between the generation of new knowledge and its application in the classroom. Educators spend a large amount of time in schools working with learners and are in the most appropriate situation to investigate the practice.

4.4 DATA COLLECTION

4.4.1 Research instrument

The questionnaire (see Appendix A) developed and utilised in this study was administered to a group of fifty-five (55) Grade 10 learners. The questionnaire probed the learners' alternative conceptions of energy - both their general perception of energy (section 2.2.1) and their conceptions regarding energy in mechanics (section 2.2.2). Learners were allocated fifty minute (50) to complete the questionnaire. The time allocated for learners to answer the questionnaire was reasonable, as they managed to finish answering the questionnaire in the allotted time. The researcher supervised the completion of the questionnaire to ensure that the learners understood all the questions. The questionnaire as measuring instrument provided a basis on which the entire research effort rests. A requirement is that the instrument used must be valid and reliable (Leedy & Ormrod, 2001:203).

The items in the questionnaires used in this study were compiled to cover the objectives of the study. It focused on alternative conceptions that learners possess about energy. Items 1 (a) to (e), i, k, and l focused on general perception of energy (see paragraph 2.2.1), while the other items dealt with energy concepts in mechanics (paragraph 2.2.2). The latter includes possible confusion of force and energy and understanding of potential and kinetic energy.

4.4.2 Validity of the instrument

In general, the validity of a measuring instrument is the extent to which the instrument measures what it is supposed to measure (Leedy & Ormrod, 2001:98). This research started to establish validity,by discussions of the questions in the questionnaire with the study leader and fellow-students, who also focused on effective teaching of energy. The instrument assessed whether the intervention strategy used in the three activity-based lessons enhanced conceptual development in mechanics to be in line with the hypothesis and the objectives stated.

4.4.3 Reliability of the instrument

The reliability of a measuring instrument is the extent to which it yields consistent results when the characteristics being measured have not changed (Leedy & Omrod, 2001:98). The reliability of the instrument used in this study was tested by means of matched items in the questionnaire, e.g. items 1 (a), (g), 2 and 3 all relate to non-living objects.

4.5 ACTIVITY-BASED INTERVENTION

The intervention consisted of three activity-based lessons (Appendix B). The concepts of work, potential energy, kinetic energy and conservation of energy were introduced. For each of these concepts, the order proposed by Lemmer and Lemmer (2005) was followed, i.e. progression from contextual to conceptual activities to formal problems. The intervention was compiled by the author. His own ideas and activities were integrated with examples given in the Grade 10 textbook of Brookes *et al.* (2005). The activities were performed in small groups so that co-operative learning could take place. There were three boys and three girls in each group.

In all the activities a problem was posed that the learners had to solve in groups. The contextual and conceptual activities utilised the strategies of verbalisation (paragraph 3.3.3) and analogical reasoning (paragraph 3.3.4). In the first contextual problem the learners were given four pictures (Figure B.1). They had to say in which of them energy is transferred in order to keep on with what is being done. During the post-activity discussion, the educator introduced the concepts of work and potential energy.

To ensure conceptual understanding of work as the product of displacement and force in the direction of the displacement, a conceptual problem was given (refer to Figure 2, Appendix B) in the second lesson. In both the contextual and conceptual problems the amount of work was perceived to be analog to the amount of fuel needed. Work was defined both by the existential definition (as the amount of energy transferred) and the procedural definition (as the product of displacement and the component of the force in the direction of the displacement). The conversion of chemical potential energy to gravitational potential energy while work was done was discussed. The learners were guided to deduce the dependency of potential energy on both the weight and the height of an object.

The concepts of gravitational potential and kinetic energy were formalised in the third lesson (paragraph 4.6.3). The learners conducted an inquiry experiment (section 3.3.4) showing them that kinetic energy depends on both the mass and velocity of an object. The learners studied the transfer of energy between two colliding balls (paragraph 4.6.4) as well as the conversion of the energy of a swinging bob. Conservation of energy during transformations was explained. The intervention ended with a formal problem of energy conversion during free-fall.

4.6 AVERAGE NORMALISED GAIN

In order to assess learning *per se*, it is necessary to have a measure that reflect the transition between knowledge states and that has a maximum dependence on instruction, with minimum dependence on learners' pre-instruction scores (Meltzer 2002). In addition, the ideal measure would be reliable in the sense that minor differences in test instrument should yield approximately the same value of learning gain.

According to Meltzer (2002), a single examination (e.g. only a post-test) yields information about a learner's knowledge state at one point in time. The primary interest of instructors in learning is transition between states. In addition to being inadequate by itself for measuring that transition performance, a single exam might be strongly correlated with a learner's pre-instructional preparation and knowledge.

A measure of learning gain should be reliable so that simple modification of the testing instrument would not lead to widely disparate results (Meltzer, 2002). The absolute gain (post-test - pre-test) score tends to correlate (negatively) with pre-test scores and is also an obstacle to isolate a measure of learning from confounding effects of pre-instruction state (Meltzer, 2002). One way of dealing with this problem is to derive a measure that normalises the gain score in a manner that takes some account of the variance in pre-test score. The use of such a measure in physics education was introduced by Hake (1998). This measure is called the average normalised gain.

According to Hake (2002a:3), the average normalised gain affords a consistent analysis of pre- and post-test data over a diverse learner population. The average normalised gain can be calculated by means of the following formula:

$$\text{Average normalised gain } (\langle g \rangle) = \frac{\text{Actual learning gain}}{\text{Maximum possible gain}}$$

The difference of the pre- and post-test percentages gives the actual learning gain. The maximum possible gain is calculated as the difference between the actual gain and the maximum possible gain (100%). Dividing the actual gain by the maximum possible gain gives the average normalised gain, < g>.

The average normalised gain is a much better indicator of the extent to which a treatment is effective than is either the actual learning gain or the post-test results (Hake, 2002b:2, Meltzer 2002). If the treatment (e.g. an intervention) yields an average normalised gain larger than 0,3 for a course, the course can be considered to be in the "interactive-engagement zone" (Hake, 2002b).

Probably the best empirical support for use of normalised gain as a reliable measure lies in the fact that <g> has now been determined for literally tens of thousands of learners in many hundreds of classes worldwide with extremely consistent results (Hake, 2002a; Meltzer, 2002). The values of <g> observed for both traditional courses and those taught by using interactive engagement methods both fall into relatively narrow bands that are reproduced with great regularity for classes at a broad range of institutions with widely varying learner demographic characteristics (including pre-test scores). This provides a strong argument that normalised gain <g> is a valid and reliable measure of learners' learning gain due to instruction (Meltzer, 2002).

4.7 SUMMARY

In this chapter the research design of the empirical study, action research aimed at determining and rectifying learners' alternative conceptions regarding energy was discussed. The intervention consisted of a sequence of three activity-based lessons that progressed from contextual to conceptual to formal problems related to the energy concept in mechanics. The average normalised gain that was used to measure the effectiveness of the intervention was motivated and defined. The results of the empirical study are given and will be discussed in the next chapter (Chapter 5)

CHAPTER 5

RESULTS AND DISCUSSION OF RESULTS

5.1 INTRODUCTION

The aim of the study was to investigate the effectiveness of a sequence of activity-based lessons to change Grade 10 learners' alternative conceptions about energy in mechanics. The data for this study was collected by means of a questionnaire administered to learners before and after the intervention. The same questionnaire was used for the pre- and post-test. The pre-test results are discussed in paragraph 5.2, followed by a discussion of the post-test results in paragraph 5.3. The pre- and post-test constituted a learning gain test, as they were a means to measure learners' learning gains (see section 4.6). The learning gain quantifies conceptual development due to the intervention (objective 2) and indicates the effectiveness of the intervention. The learning gains that were obtained due to the intervention are reported and interpreted in paragraph 5.4.

5.2 PRE-TEST RESULTS

5.2.1 Learners' responses to Item 1

The results of the questionnaire obtained from the fifty-five (N=55) learners who participated in this empirical study were processed and analysed. Table 5.1. summarises the learners' responses to the first pre-test item of the questionnaire. They had to indicate whether or not the listed objects possessed energy.

TABLE 5.1. PRE-TEST RESULTS (N=55) FOR ITEM 1

CAN THE FOLLOWING OBJECTS POSSESS ENERGY?	YES RESPONSE		NO RESPONSE	
	NUMBER	%	NUMBER	%
a) Rock	23	42	32	58
b) Tree	33	60	22	40
c) Dog	37	67	18	33
d) Learner	54	98	1	2
e) An apple hanging on a tree	15	27	40	73
g) Non-living object, such as a ball	19	35	36	65
i) Does a sleeping dog possess energy?	21	38	34	62
k) Food	18	33	37	67
l) Fuel	10	18	45	82

5.2.2 Discussion of pre-test results (Item 1)

The learners' responses to item 1 were evaluated in terms of the categories of Watts (1983), which were discussed in paragraph 2.1. A detailed analysis of the motivations given by the learners is summarised in Appendix C. Only the motivations given by the largest groups of learners are discussed in this paragraph to determine general trends in their reasoning. The other learners gave either non-recurrent or no motivations.

a) Rock

Twenty-three (42%) of the learners indicated that the rock possessed energy. The most common reason given was that it was heavy (15%) or that it contained sand or water. These reasons referred to the features of the rock. The learners also gave reasons that related to what could be done with a rock, namely that you use energy to pick it up or throw it (11%) or that one could use it for building (9%). The depository model of energy as well as the functional model (see paragraph 2.2.1) were displayed by these learners.

The thirty-two (58%) of the learners who responded that a rock could not possess energy, mainly gave a reasons that a rock did not live (18%) nor did it move (15%). They consequently held a human-centred model of energy, or related energy to activity.

b) Tree

Thirty-three (60%) of the learners indicated that a tree possessed energy. According to the motivation given by the largest group of these learners, the tree had energy because it gave us food (13%), while 11% said that it had air. The energy-as-ingredient-perception was thus displayed. The 9% of the learners who said that the tree got energy from the sun gave a scientifically acceptable answer.

Of the 40% learners who responded that a tree did not possess energy, 5% ascribed it to the fact that a tree did not move and 5% simply said that it did not have energy. The other 30% of learners gave a variety of reasons or mostly gave no reason at all.

c) Dog

Thirty-seven (67%) of the learners indicated that a dog possessed energy. According to 22% of the learners, the dog had energy because it could run; while18% said that it was living. The human perception (paragraph 2.2.1) that energy was associated with a living thing was displayed. The 15% of the learners who said that a dog had energy because it was an animal attributed human features to animals. The perception that energy and power were the same concept was displayed by 11% of the learners. They used the terms energy and power interchangeably, which is a problem discussed in section 2.3.2.

Of the 33% learners who responded that a dog did not possess energy, 11% said it was not a human being and it was not strong. The energy as human-centred.

perception was displayed again (paragraph 2.2.1). Some 11% gave a variety of reasons and 4% gave no reason at all.

d) Learner

Fifty-four (98%) of the learners indicated that a learner possessed energy. The most common reason given was that she/he was living (36%). The learners also gave as a reason the fact that the learner could eat (18%). As in the previous cases, the majority of learners revealed a human-centred view.

One (2%) of the learners who responded that a learner could not possess energy gave as a reason that a learner had energy when she/he used it. This indicates their usage of the depository model of energy.

e) An apple hanging on a tree

Fifteen (27%) of the learners indicated that a hanging apple possessed energy. According to the largest group of these learners (11%), the tree was growing and it gave us oxygen (energy as functional), while 7% of the learners said it provided us with food (energy as ingredient). The other 7% said that the tree was living. Another 4% of the learners gave a variety of reasons.

The forty (73%) learners who responded that an apple hanging on tree could not possess energy, mainly reasoned that it was just hanging on a tree (15%), or it was not moving (13%). Some learners reasoned that an apple was non-living (18%), or that no force was needed to take it from the tree (11%).

g) Non-living object such as a ball

Nineteen (35%) of the learners indicated that a non-living object such as a ball possessed energy because it could move. The energy as an obvious activity-perception was displayed. Some learners reasoned that when a boy played with a ball he ran and that running gave energy (5%) or if it was kicked it would possess energy (25%).

Thirty-six (65%) of the learners who responded that a non-living object such as a ball could not possess energy, mainly gave the reasons that a non-living object did not have energy because it was not living (33%), the ball was not moving (22%) and had no power (7%).

i) Does a sleeping dog possess energy?

Less than one third of the learners (30%) said that a sleeping dog possessed energy. The most common reason given was that it was living (18%) or it could breathe (7%). The 1% of the learners who said that if it was not asleep it could move, perceived energy as obvious activity.

The 62% of learners who responded that a sleeping dog could possess energy, mainly reasoned that it was not doing anything (18%) and it was not moving (11%). The other learners said all parts of the body were related (11%) and when it was not sleeping, no energy was used at that moment (7%). The perception of energy as obvious activity was again evident. The other 11% gave a variety of reasons.

j) Does force cause motion?

Forty-four (73%) of learners believed that force caused motion. The most common reason given was that force caused motion; for work to be done, force had to be applied (27%). The learners also gave as reason that we use energy to force something to occur (18%) and that a wheelbarrow needed a force to move (18%). The others gave a variety of reasons.

Of the fifteen (27%) of the learners who responded that force could not cause motion said energy was something that could cause something to move (7%). Some 4% of the learners said we did not need force for an object to move. The other 4% of learners said force was power and we use it to make an object move. The other learners said force did not work like energy (5%). The other 2% of learners gave a variety of reasons.

k) Food

Eighteen (33%) of the learners indicated that food possessed energy. According to the largest group of these learners (9%), we cannot live without food (9%) and if we ate we could do any kind of job (2%). The learners said food gave us strength (5%) and it gave one's body energy (4%). The other 7% said it gave us power to do work. The other 4% of learners said nutrients in food gave us energy.

As many as 67% of learners indicated that energy was not stored in food and mainly gave reasons that it only gave us energy when you ate it (energy as ingredient)(18%).Some 21% of learners said energy was not stored in food while 13% gave a variety of reasons.

l) Fuel

Ten (18%) of the learners indicated that fuel possessed energy, the most common reason given being that it made a car move(5%); it had power (4%) and fuel had energy only in cars (4%). The other 2% of learners said that fuel had chemical energy - a scientifically accepted answer.

The 82% of learners who indicated that fuel could not possess energy, said we could not drink it (33%), it was a gas (22%) and it was not good for a human being (2%). The other (7%) gave a variety of reasons.

5.2.3 Analyses of alternative conceptions in pre-test results (Item 1)

Table 5.1 summarises the pre-test results of the first question in which the learners had to indicate and motivate whether the given objects could have energy. The number of learners who answered YES or NO was given, and the motivations for their answers were discussed in paragraph 5.2.2. These results were further analysed to determine the frequencies of occurrence of the different alternative conceptions revealed by the learners (Table 5.2). Five of seven categories of alternative conceptions regarding energy as identified by Watts (1983) were found in the learners' responses. The last column of Table 5.2. gives the percentage of learners who clearly demonstrated the alternative perceptions. The other learners either did not give a reason, or gave dissimilar reasons.

Table 5.2 Summary of the categories of alternative conceptions that were found in learners' responses in the pre-test.

Does it possess energy?	Response	No of learners (%)	Most commonly found alternative perceptions	% occurrence
Rock	No	32 (58 %)	Human-centred	15
			Energy as activity	15
	Yes	23 (42 %)	Depository model	20
			Energy is functional	9
Tree	No	22 (40 %)	Energy as activity	5 %
			Depository model	5 %
	Yes	33 (60 %)	Depository model	20 %
			Energy as an ingredient	13 %
			Human-centred	5 %
Dog	No	18 (33 %)	Human-centred	18 %
	Yes	37 (67 %)	Human-centred	55 %
			Depository model	11 %
Learner	No	2 (4 %)	Energy is functional	4 %
	Yes	53 (96 %)	Human-centred	54 %
			Energy is functional	27 %
Apple hanging from tree	No	40 (73 %)	Human-centred	31 %
			activity	15 %
			Depository model	11 %
	Yes	15 (27 %)	Ingredient	18 %
			Human-centred	7 %
Ball	No	36 (65 %)	Human-centred	33 %
			Energy as activity	22 %
			Depository model	7 %
	Yes	19 (35 %)	Energy as activity	30 %
Sleeping dog	No	34 (62 %)	Energy as activity	37 %
			Human-centred	29 %

	Yes	21 (38 %)	Human-centred	25 %
			Energy as activity	11 %
Food	No	37 (67 %)	Depository model	36 %
			Energy as ingredient	18 %
	Yes	18 (33 %)	Energy is functional	16 %
			Energy as ingredient	9 %
Fuel	No	45 (82 %)	Energy as ingredient	53 %
	Yes	10 (18 %)	Energy is functional	9 %
			Depository model	6 %

The results summarised in Table 5.2 show that the human-centred perception occurred in all the cases, i.e. for all the objects listed in Item1. Sometimes, it was even used by learners who agreed as well as those who disagreed that the given object could have energy. For example, in the case of the dog, human-centred responses in support of a dog having energy were that it was living, while human-centred responses that differed from this statement included that a dog was not strong or was not a human being. Another commonly found alternative conception was the association of energy with activity, specifically movement. Responses that referred to energy as causal agent, i.e. a source of activity based on energy stored within it, were categorised as the depository model. Examples of energy sources are food and fuel.

Some learners perceived various objects to be functional, e.g. a rock, learner, food and fuel. These objects could either be used to do something (e.g. a rock can be used for building) or can do work itself (e.g. a learner) or it provides energy to a human or car to do work (the food and fuel). According to the energy as ingredient perception, some learners considered energy as a dormant ingredient within objects that needed a trigger to release it. For instance, food (including apples) gave energy to people when they ate it, while fuel only provided energy when it was used inside a motor car.

The alternative conceptions displayed depended on the context of the question. The human-centred perception was used by the largest percentages of learners in cases of non-living objects (rock, apple and ball) as well as living objects (learner and dog).

When referring to food, the largest group of learners (36%) used the depository model of energy, while energy in fuel was mostly (53%) perceived as ingredient.

The learners responded consistently in similar contexts. For example, learners who said that a rock could not have energy because it was not alive gave the same reason in other related questions, e.g. why a ball could not have energy, but a dog (even one that slept) could. These learners further indicated that the non-living box pushed by the boy (question 2) could not have energy, while the boy had energy. The coherence and consistency in their answers strengthen the reliability of the results.

5.2.4. Items referring to force and energy

Three items were included in the questionnaire in order to determine how learners differentiate between the concepts of force and energy. The results are summarized in Table 5.3

TABLE 5.3 Results for items referring to energy and force

QUESTION	YES RESPONSE		NO RESPONSE	
	NUMBER	%	NUMBER	%
f) Is energy, power & force the same concept	40	73	15	27
h) Does energy cause motion?	44	80	11	20
j) Does force cause motion?	40	73	15	27

The results of Table 5.1.2 show the following:

f) Is energy, power and force the same concept?

Forty (73%) of the learners said that energy, power and force were the same concept. This might be a result of their everyday usage of the concept in their vernacular (see paragraph 2.3.2). The reasons given by the learners included that one could not make anything without using energy, power and force (18%) and that these concepts were all related to work (11%), and they were interchangeable (27%). The other 16% of learners gave a variety of reasons.

The fifteen (27%) of the learners who responded that energy, power and force were not the same concepts did not explain the terms scientifically. Only 2% of the learners said they were not the same concept because they did not perform the same job. The other 25% of learners mostly gave no reason at all.

h) Does energy cause motion?

Forty-four (80%) learners indicated that energy caused motion. The most commonly used reason was that movement of any kind involved energy (22%). The perception of energy as an activity was revealed by the learners. The other learners reasoned that energy caused something to occur (15%) or energy was the ability to do things (15%). These latter reasons differ from the scientific definition that energy is the ability to do work, where the concept of work has a specific meaning.

Eleven (20%) of learners who responded that energy did not cause motion, mainly motivated their answer by reasoning that energy was an occurrence and not the cause of action or motion (i.e. not an obvious activity). Some 4% of the learners said that motion did not use energy.

j) Does force cause motion?

Forty-four (73%) of learners believed that force caused motion. The most common reason given was that force caused motion; for work to be done, force had to be applied (27%). The learners also gave as reason that we use energy to force something to occur (18%) and that a wheelbarrow needed a force to move (18%). The others gave a variety of reasons.

Of the fifteen (27%) of the learners who responded that force could cause motion said energy was something that could cause something to move (7%). Some 4% of the learners said we did not need force for an object to move. The other 4% of learners said force was power and we use it to make an object move. The other learners said force did not work like energy (5%). The other 2% of learners gave a variety of reasons.

5.2.5 Pre-test results: Items 2 and 3

The results obtained for items 2 and 3 of the questionnaire are as follows:

Item 2

Unlike Item 1 where the learners had to indicate whether objects could possess energy, item 2 sketched a situation for which the learners had to specify the energy. The situation was that of a man pushing a box uphill. The vast majority of learners (80%) focused on the man (human-centred) as the one who had energy, since he could push the box to the top of the hill (energy is functional). Some 20% of the learners said that the box was moving but it had no energy because it was non-living (human-centred perception). For these learners the human-centred perception carried more weight than the perception of energy as obvious motion.

Item 3

Item 3 tested whether learners related kinetic energy to the mass and/or the velocity of objects. Almost all the learners (91%) reasoned that ball B should have more energy because it was bigger than ball A. The learners did not take the velocities of the objects into account. They only focussed on the visual size of the ball. The remaining 9% of the learners did not respond to this question.

5.3 Post-test results

5.3.1 Post-test results Item 1

The results of the post test are displayed in Table 5.4.

TABLE 5.4. POST-TEST RESULTS (N=55) FOR ITEM 1

CAN THE FOLLOWING OBJECT POSSESS ENERGY	YES		NO	
	NUMBER	%	NUMBER	%
a) Rock	40	73	15	27
b) Tree	30	55	25	45
c) Dog	50	91	5	9
d) Learner	55	100	0	0
e) An apple hanging on a tree	50	91	5	9
g) Non-living object such as a ball	40	73	15	27
i) Does a sleeping dog possess energy?	44	80	11	20
k)Food	48	87	7	13
l) Fuel	43	78	12	22

5.3.2 ANALYSIS OF POST-TEST RESULTS

Item 1 (a)

The energy possessed by the rock was named as potential energy by 40 (73%) of the learners. The other learners did not give a reason why they said a rock had energy. Approximately a quarter of the learners (27%) clung to their perception that a non-living rock could have energy.

Item 1 (b)

About half of the learners (55%) said that the tree could possess energy. The learners' responses still showed signs of the depository model and energy as an ingredient.

Item 1 (c)

Fifty (91%) of the learners used a scientifically acceptable explanation, namely that although the dog was at rest (it was not moving) it possessed potential energy. When it started to move it had kinetic energy.

Item 1 (d)

Forty (72%) of the learners referred to a learner as having energy because he/she had mass and he/she could move. The kind of energy associated with movement was named as kinetic energy.

Item 1 (e)

Fifty (91%) of learners said both concepts were not the same in science. They were able to define these concepts scientifically, namely power was the rate at which work was done, energy was the ability to do work, and the force was a push or a pull. Only 5 (9%) learners said that the concepts were not the same but they still confused work, power, force and energy. This could be because the educator (researcher) did not focus much on these concepts during intervention.

Item 1 (g)

Forty (73%) learners managed to define potential energy as energy at rest. They had the scientific meaning of potential energy and kinetic energy correct. Fifteen (27%) of the learners still had mixed ideas - sometimes living and other times potential energy.

Item 1(i)

Forty-four (80%) of the learners said a dog had energy because it could move and this change in the position of the dog was referred to as kinetic energy.

Item (k)

Forty-eight (84%) of the learners said energy was stored in food. There was a conceptual change in learners' belief that energy was not stored in food (energy as ingredient).

Item (i)

Forty-three (78%) said a fuel had chemical potential energy. A conceptual change in learners was accomplished.

Item (2)

Eighty (80%) of learners said a box and man had energy. They dido not refer to a non-living and living thing.

Item (3)

Fifty-five (100%) learners said the kinetic energy of the object did not depend on the mass of the object and the only factor that depended on it was the velocity.

5.3.3. Analysis of post-test results for force and energy

The responses of learners to the items regarding the concepts of force and energy are given in Table 5.5. A discussion follows below the Table.

Table 5.5. Post-test results for force and energy

QUESTION	YES RESPONSE		NO RESPONSE	
	NUMBER	%	NUMBER	%
f) Are energy, force, and power the same concepts	5	9	50	91
h) Does energy cause motion?	46	84	9	16
j) Does force cause motion?	49	89	6	11

Item (f)

Nearly all the learners (91 %) knew that energy, force and power are different concepts in science. They were able to give acceptable definitions for these concepts.

Item 1 (h)

Forty-six (84%) of the learners managed to explain energy scientifically as the ability to do work. Also, for work to be done the object had to move and in order for work to be done, the applied force had to be able to move the object. A conceptual change was accomplished in this item.

Item (j)

Eighty-nine (89%) learners defined force scientifically as a push or a pull.

5.3.4 Discussion of the post-test results

The concept of potential energy

One of the major deficiencies revealed in the pre-test results was that the learners did not understand the concept of potential energy, and consequently thought that objects that did not move could not have energy. Due to the intervention, this deficiency was rectified, because the learners used the concept of potential energy to explain why the following objects named in items 1 and 2 could possess energy.

Item 1(a): The rock could have potential energy (gravitational), because of its mass and position (i.e. gravitational potential energy). As many as 73% of the learners gave the correct answer.

Item 1(c): 91% of the learners correctly said that a dog had potential energy (chemical) even when it was at rest. The potential energy was converted to kinetic energy when it started to move. The energy associated with movement was called kinetic energy.

Item 1(d): All learners (100%) believed that a learner had energy. In their motivations 70% of them referred to the learner's mass, potential energy (chemical) or ability to move (kinetic energy).

Item 1 (e): According to 91% of the learners an apple hanging on a tree had potential energy (gravitational) because of its mass and height. None of these learners referred to features of a tree anymore as they did in the pre-test.

Item 1(g): 73% of the learners said that a ball could have potential energy and when it started to roll, potential energy was transformed to kinetic energy. According to 27% of the learners, a ball had energy when it changed its position (i.e. moved).

Item 1 (i): 80% of the learners knew that a sleeping dog had potential energy (chemical) that enabled it to move when it woke up (conversion to kinetic energy).

Items (k) and (l): The results show that 84% of the learners knew that energy (chemical potential) was stored in food, while 78% knew that it was stored in fuel.

Item 2: According to 80% of the learners both the man and the box had energy: the man got energy from food, while the box gained potential energy as it was moved up the hill.

Alternative conceptions

Although the majority of the learners showed a conceptual change towards the scientific concept of energy, some of them still revealed alternative conceptions in the post-test, namely:

In item I (b), more than half (55%) of the learners said that a tree had energy. Many of these learners as well as those who answered negatively related energy to being alive (human-centred), or gave us food or air (energy as ingredient). Although all (100%) of the learners knew that a learner could have energy, about 30% ascribed to the learner being alive (Item 1(d)).

All five categories of alternative conceptions occurred in some of the learners' responses. The human-centred association of living beings with energy has been found to be one of the most pervasive alternative conceptions. This is in accord with results obtained by other researchers (e.g. Trumper, 1990).

Scientific terminology

The confusion of scientific terms as energy, force, power and work, has largely been rectified in the intervention. In item 1 (f), 91% of the learners knew that energy, force and power were different concepts in science. These learners managed to define the concepts scientifically correct. About 80% of the learners related energy and work in item 1 (h) by the definition that energy was the ability do work. According to 89% of the learners force was associated with movement. Force was mostly defined as a push or pull.

5.4. AVERAGE NORMALISED GAINS

To quantify the success of the intervention to remedy learners' alternative perceptions, the average normalised gains were calculated, using the formula of Hake (1998) given in paragraph 4.5). The normalised gains for every object in item 1 as well as for the average of the questionnaire are shown in Table 5.4.

TABLE 5.4: AVERAGE NORMALISED GAINS OBTAINED PER ITEM

ITEM	PRE-TEST %	POST-TEST %	IMPROVEMENT %	GAIN	PERCENTAGE GAIN
A	42	73	31	0.53	53
B	55	60	5	0.1	10
C	67	91	24	0.72	72
D	98	100	02	1	10
E	27	91	64	0.88	88
F	27	91	64	0.88	88
G	35	73	38	0.58	58
H	80	84	4	0.2	20
I	38	80	42	0.68	68
J	73	89	16	0.59	59
K	33	87	54	0.80	80
L	18	78	60	0.73	73
AVE	49. 4	83.1		0.5	50

An illustration of how the average normalised gain was calculated is illustrated by means of the following example. The averages obtained for the pre- and post-test (i.e. the last row of Table 5.3 is used:

Actual percentage gain = post-test score - pre test
= 83.1 – 49.4
=32.9

Maximum possible gain = Total possible gain - actual gain
=100 -32, 9
=67.1

$$\text{Average normalised gain} = \frac{\text{Actual percentage}}{\text{Maximum possible gain}} = \frac{32.9}{67.1} = 0.49 = 50\%$$

The average of the results from pre-test to post-test increased tremendously (refer to last row in Table 5.3), namely from a pre-test average of 49.4% to a post-test average of 83.1%. The gain is 0.5 (or 50%). The average gain of 50% falls in the "interactive engagement zone" (Hake, 2002b). The effectiveness of the strategies used in the intervention is thus comparable with contemporary interactive engagement strategies.

Considering the individual items, the largest normalised learning gains were obtained in the cases of the apple hanging from the tree, food, and fuel. All three these objects/substances involved the concept of potential energy (gravitational or chemical). This confirms the improved understanding of this concept by the learners.

The largest gains (>80%) were obtained for items e and f because an anthropocentric (energy is associated with human beings) alternative conception has been changed. Items b, d, and h showed gains of 20% and below because an activity (energy is an obvious activity) and anthropocentric alternative conceptions had been changed. The activity-based strategy followed in the intervention was therefore more effective to change anthropocentric alternative conception of energy as an activity. This is an interesting result in terms of Chi's conceptual change ideas (Chi *et al.*, 1994)

5.5 SUMMARY

This chapter has reported the results obtained in the empirical study described in Chapter 4. The results of the pre-test, post-test and the learning gains were given and analysed. Five categories of alternative conceptions occurred in the pre-test responses of the learners. They also confused terminology that have distinct meanings in science, namely force, energy and power. These problems were remedied to a satisfactory extent. The learning gain of 50% is 30% larger than that reported for traditional teaching and falls in the "interactive zone". Conclusions and recommendations that follow from these results are given in Chapter 6.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The aim of the study was to investigate the effectiveness of an activity-based learning and teaching strategy on learners' understanding of energy in mechanics (paragraph 1.2). The methodology and results of the empirical research is summarized in paragraph 6.2. The recommendations and conclusions given in paragraph 6.3 and 6.4 are based on the research hypothesis (paragraph 1.4) and objectives (paragraph 1.3) of the study.

6.2 SUMMARY OF METHODOLOGY AND RESULTS

The first objectives of the empirical study was to determine the alternative conceptions of Grade 10 learners about the concept of energy and identify them in terms of the classification of Watts (1983). This objective was accomplished by means of a questionnaire (Appendix A). The questionnaire established the group of Grade 10 learners' ideas about what energy is as well as how they applied these ideas. On ground of these results an instructional sequence (Appendix B) compromising of activity-based lessons in mechanics was compiled and tested (Objective 2). The instructional sequence progressed from contextual to conceptual to formal learning. The effectiveness of the intervention (aim of the study) was determined by calculation of the average normalized gain.

An activity-based approach was used in the intervention because it

(a) is in line with the requirements of the National Curriculum Statements (Department of Education, 2003 a and b);

(b) is constructivitic, since it provides opportunities for learners to express their pre-knowledge that can then be remedied by the facilitator (Taraban *et al.*, 2007);

(c) is learner-centred, since it encourages active learner involvement (Ramsden, 1994, Taraban *et al.,* 2007);

(d) motivates and enhance learning (Ramsden, 1994);

(e) especially benefits disadvantaged learners (Donnellan & Roberts, 1985).

The results showed that the most common view of energy before instruction was anthropocentric and anthropomorphic in nature. Accordingly, learners believed that only objects that were human or revealed human attributes such as the ability to eat, motion and strength, could have energy. The learners also displayed the depository or functional model of energy, perceived energy as an ingredient, obvious activity or product. Other conceptual problems included that the learners did not understand scientific concepts such as potential energy and confused the concepts of energy and force.

Five of the seven categories of alternative conceptions regarding energy identified by Watts (1983) appeared amongst a large percentage of the Grade 10 learners. The alternative conceptions displayed depended on the context. For example, learners used human-centred reasoning when referring to a dog, but energy as activity in the case of a sleeping dog. Still, the learners responded consistently in similar contexts, e.g. in case of non-living objects such as a rock, ball and box.

The high normalised learning gain of 50 % achieved by the intervention indicated the effectiveness of the activity-based instructional sequence to change the learners' alternative conceptions to a scientifically accepted understanding of the concept of energy in mechanics.

Since the aim of the study concerned effective teaching of the concept of energy, the instructional strategy that was followed is summarized. The teaching implemented a contextual approach (paragraph 3.4) in activity-based learning (paragraph 3.3.1) in accordance to the constructivist learning theory (paragragh 3.2).

Learners' work in small groups so that co-operative learning could take place. In these groups they discussed the solutions of a variety of problems (paragraph 3.3.2) and performed an inquiry experiment (paragraph 3.3.5).The order of activities followed the contextual didactical approach (paragraph 3.4). In this way the learners were guided to change their alternative conceptions to scientific accepted ideas. The intervention was consequently based on the constructivist learning theory (paragraph 3.2).

When learners are given familiar contexts (e.g. the pictures in Figure B-1), they were found eager to express their own views. Through verbalisation (paragraph 3.3.3) they revealed their alternative conceptions as well as their anchoring conceptions. For example, in the variety of contexts given in Figure B-1, a learner may say that the horse and boat can transfer energy, because the one eats and the other uses fuel. This can be used as anchoring ideas to explain chemical potential energy. By means of analogous reasoning (paragraph 3.3.4), the idea of gravitational potential energy was introduced.

Chemical potential energy also formed the anchoring idea in the conceptual problem demonstrated in Figure B-2. Learners' everyday knowledge and analogous reasoning was used to explain the dependency of potential energy on weight and height. Formalization of the concept of potential energy followed naturally.

Similarly, the concept of kinetic energy was introduced by a contextual example (cutting a tree by swinging an axe). In an inquiry experiment learners' alternative conception that a more massive object will always have more kinetic energy, was treated. Conceptual understanding of the concept of energy was followed by formalization.

The context of a playground swing served as anchoring context for the simple pendulum in an interactive demonstration. Learners' attention is focussed on the changes in height and velocity of the swinging pendulum. This promotes a conceptual understanding of conversion of energy as well as conservation of mechanical energy. Formal calculations are done, first with the pendulum, and then with a falling ball.

The high normalized gain was consequently accomplished by an effective teaching sequence based on the constructivist learning theory.

6.3 CONCLUSIONS

Most researchers (Chin & Brewer; 1998:104) contend that the quality of prior knowledge is perceived to have powerful effects on the teaching and learning process in science. If educators can probe learners' prior knowledge, they can identify learners' alternative conceptions and this will set the scene for the need to learn and teach according to what learners already know. Teaching strategies should consequently be based on the constructivist approach in order to effectively accomplish conceptual change. A combination of different teaching strategies should be utilized to make different cognitive demands upon learners and provide for individual differences.

The high percentage of occurrence of learners' alternative conceptions about energy and their deficiency in an understanding of the scientific concepts as revealed by the pre-test is disturbing. The Grade 10 learners had been exposed to the concept of energy from grades R to 9 in the physics module *Energy and Change.* During these years of instruction their alternative conceptions were not sufficiently taken into account (Edwards, 2007). It also seems that scientific terminology such as potential and kinetic energy and force were not introduced effectively.

The activity-based sequence of this study that progressed from contextual to conceptual to formal understanding was proved to be effective with an average normalised learning gain of 50%. This high gain shows the success of the intervention to accomplish conceptual change towards the correct scientific conceptions. The sequence of activities successfully enhanced the development of scientific conceptions. The results stress the necessity of implementation of the constructivist principle that learners' initial understanding should be engaged and their conceptual understanding appropriately developed.

The average normalised gain for the questionnaire was 0, 5 (or 50%). This percentage is much higher than the 20% gain for traditional teaching methods and the 40% gain for interactive engagement strategies that Redish *et al.* (1997) reported. According to Hake (2002), a treatment (e.g. an intervention) that yields a gain larger than 30% can be considered to be in the "interactive zone", i.e. as effective as interactive engagement strategies. This means that a practically significant improvement in the understanding of the concept of energy was accomplished due to the intervention. The learners' alternative conceptions were addressed efficiently and a conceptual change was accomplished. The most prominent was the change from the human-centred energy perception to scientific explanations in terms of potential energy.

From the discussions in paragraphs 6.2 and 6.3 it can be deduced that the reserach

objectives

(1) Determine the alternative conceptions of Grade 10 learners about the concept of energy and identify them in terms of the classification of Watts (1983); and

(2) compile and test an instructional sequence compromising of activity-based lessons in mechanics to accomplish conceptual change accomplished and the hypothesis (Grade 10 learners who participate in activity-based learning of energy demonstrate a larger learning gain compared to that of traditional instruction) proved to be valid.

Recommendations for effective science teaching follow in the next paragraph.

6.4 RECOMMENDATIONS

Although the case study reported here involved a sample of only 55 learners, the high learning gain obtained shows the effectiveness of the intervention. It is therefore justified that this activity-based learning approach be tested with a larger sample of learners. Further research needs to be done to obtain statistically significant results.

The poor pre-test results show that the learners' alternative conceptions were not efficiently addressed in lower grades. This could be due to different factors (paragraph 2.3), e.g. strong association with their vernacular conceptions, ineffective teaching and inappropriate textbooks. This result necessitates an investigation into what science is learnt and how it is learnt in all grades.

There is a special need to understand how learners learn physics concepts in African languages without introducing or enhancing alternative conception in the classroom.

It is true that learners live within a community in schools that have its own way of thinking and talking about events and phenomena that are of interest to scientists. This way of thinking and talking leads to alternative conceptions that learners grow up with. Research has to be done concerning how best we as educators can teach physics to African language speakers.

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APPENDIX A: QUESTIONNAIRE

NAME:……………………………………………GENDER: BOY/GIRL

DATE:…………………….. SCHOOOL………………………

1) Can the following objects possess energy?

	YES / NO	MOTIVATION
a)Rock		
b)Tree		
c)Dog		
d)Learner		
e) An apple hanging on a tree		
f) Is energy and force the same concepts		
g) Can a non living object like ball possess energy		
h) Does energy cause motion		
i) Does a sleeping dog possess energy		
j) Does force cause motion		
k) Food		
l) Fuel		

2. A man pushes a box up a hill. Explain, using energy, what happens……………………………………………………………………………

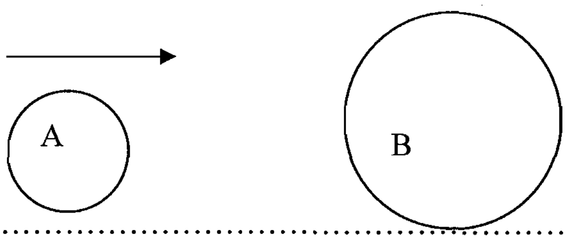
……….....……………………………………………………………………

3) Ball A is smaller than ball B. Ball A moves towards the right and bumps into a stationary ball B. After the collision ball B has

A) More kinetic energy than ball A had before the collision.

B) Less kinetic energy than ball A

C) As much energy as Ball A



………………………………………………………………………………..

Reason for answer: ……………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

APPENDIX B: INTERVENTION

1. Contextual problem

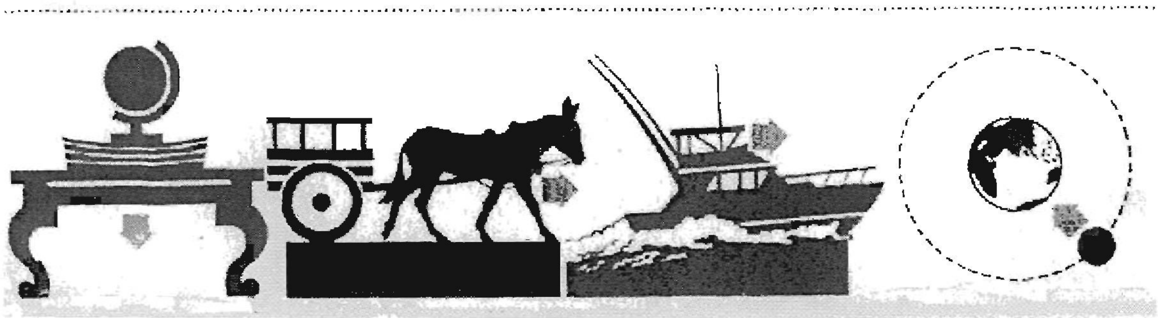


Figure 1 (Copied from Brookes *et al.*, 2005)

In which of the tasks shown in Figure 1 are energy transferred?

What energy transfers take place?

2. Conceptual problem

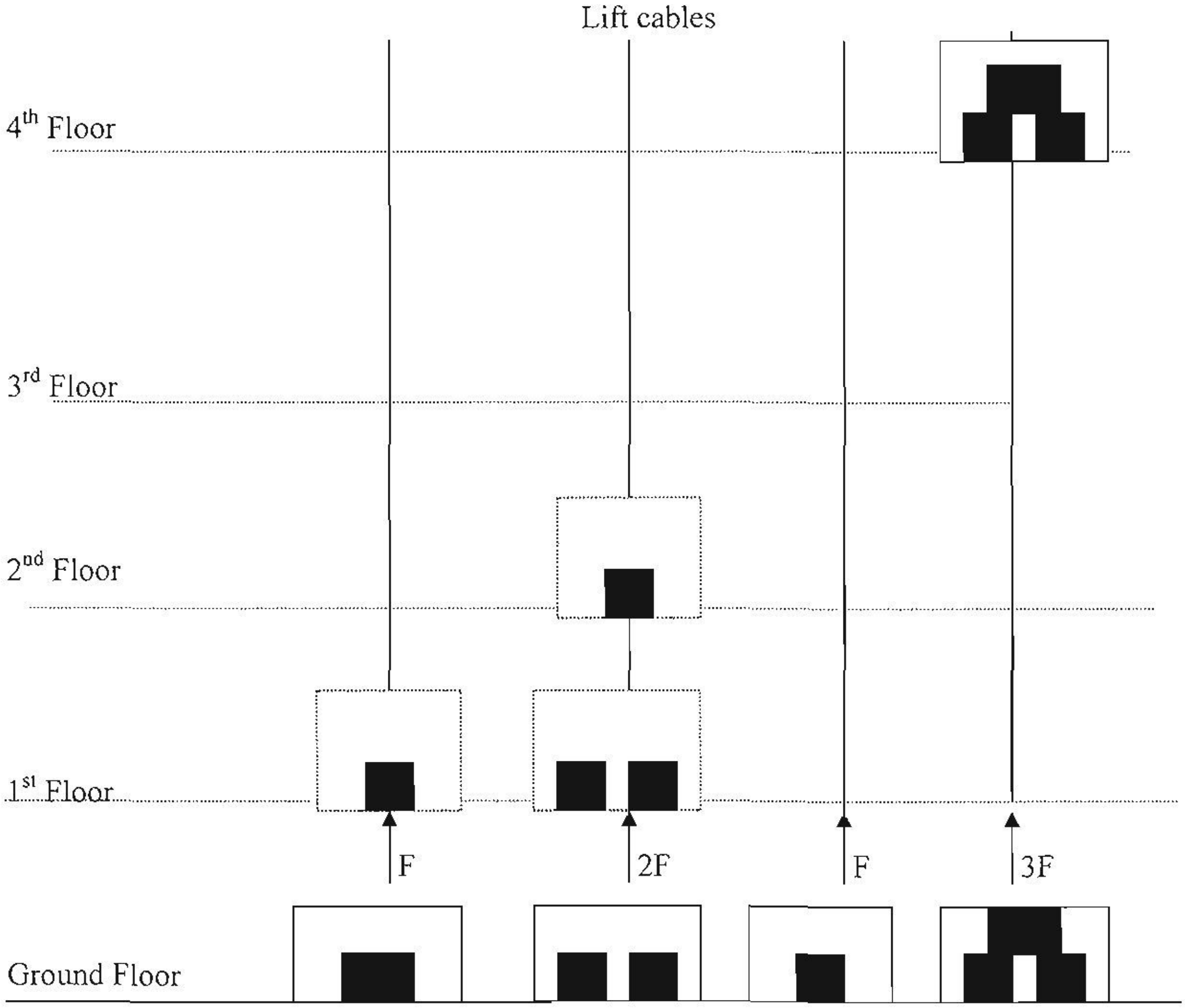


FIGURE 2. A motor -driven lift that raises different loads through different displacements at constant speed (Brookes *et al.*, 2005)

Referring to Figure 2, answer the following questions (Brookes *et al.*, 2005)

1) How much fuel will be used to raise a load three times bigger than a single load?

2) How much fuel will be used to raise a load five times bigger than a single load by seven floors?

3) Explain how you got your answers.

Post-activity discussion

After this learner activity, the learners discussed their findings with the educator. They concluded that the amount of fuel used in a task of this nature was directly proportional to the product of the force (f) acting and the displacement(s) in the direction of the force. The product of force and displacement measures the total amount of energy transferred from the fuel. The educator explained that the energy transferred from the fuel was not destroyed but was stored in a different way in the raised lift.

3. Concept formation

The energy stored in fuels (or foods) is called chemical potential energy, while the energy possessed by a raised load is called gravitational potential energy. The energy stored in a raised load may in turn be transformed into other energy forms when the load falls. The product force multiply displacement is not called 'energy' but the amount of energy transferred from one form to another and is called work. It follows that the work done equals the energy transferred from one form to another. The amount of work done equals the energy transferred. When work is done by a body, energy is transferred from the body. Similarly, when work is done on a body, energy is transferred to the body. Energy is something that is stored in different ways, for example, in fuels, raised loads and moving bodies (living and non-living), and it exists in a variety of interchangeable forms. If a substance or a body possesses energy, it is possible to transfer energy from it. Work is the amount of energy transferred and work is therefore measured in the same units than energy, namely joules (J).

Gravitational potential energy

According to Brookes *et al.* (2005: 50), gravitational potential energy is "stored" energy that a body has because of its position in the earth's gravitational field. The formula for gravitational potential energy is $E_P = mgh$, where m is the mass of the body, g is the gravitational acceleration, and h is the vertical displacement (increased).

After defining the concept, the educator asked the learners to answer the question related to this concept given on the activity sheet. Learners were supposed to calculate the gravitational potential energy gained by a non-living object (box) of a mass of 150 kg when it is raised through a vertical height of 20 m. Take g =10 $m.s^{-2}$.

Kinetic energy

The energy possessed by a moving body (non-living or living) is called kinetic energy (E_K). A moving body such as a person cutting a tree by swinging an axe can do work as it is brought to rest by the force exerted upon it as it cuts into a tree trunk. In the absence of friction, the kinetic energy transferred to a body originally at rest is equal to the work done in accelerating the body. The kinetic energy possessed by a body is calculated by the formula, $E_K = \frac{1}{2} mv^2$, where m is the mass of the body and v is the velocity.

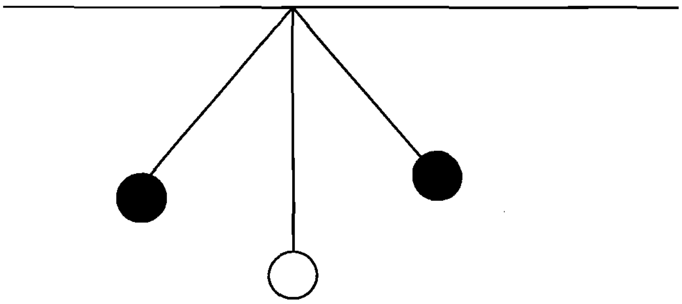
4. Inquiry experiment: Kinetic energy

After defining the concepts of potential energy, the educator asked learners to perform a simple inquiry experiment where they had two balls of masses 0, 2 kg and 0, 4 kg respectively which they had to place 5 m apart. The learners let the 0, 2 kg ball roll towards the 0, 4 kg ball, which was stationary and they recorded the time it took to bump into a 0, 4 kg ball by using a stop watch. Immediately after it had touched the second ball of mass 0, 4 kg they stopped the watch. The velocity of the 0.4 kg ball before collision was taken as 0 $m.s^{-1}$ because it was not moving. The researcher asked them to calculate the kinetic energy of the two balls before collision. They then had to say which one had more energy.

From their calculation it was found that the ball of mass 0, 2 kg had more kinetic energy than the ball of 0, 4 kg. This proved to them that it was not always the case that the bigger the mass of the body the bigger the energy

5. Interactive demonstration: Conservation of energy of mechanical energy

The educator introduced the concept of mechanical energy. Kinetic energy and gravitational potential energy are together referred to as mechanical energy. The mechanical energy of a system at a particular time is the sum of its gravitational potential energy and kinetic energy at that moment. Mechanical energy is conserved on a frictionless surface.



The educator let learners swing the bob of the pendulum where m was the mass of the body and v the velocity. Using the lowest point of the swing of the bob as zero height, the potential energy of the bob at the highest point, vertical height (where velocity is zero) is $E_p = mgh$.

At the lowest point of each swing the learners were asked how much potential energy the bob had, taking into account that the lowest point was considered to be at zero height.

The bob reached its greatest velocity (v) at the lowest point, its kinetic energy at that point being $E_k = \frac{1}{2} mv^2$

The educator explains the concept of conservation of mechanical energy.

6. Formal problem

The researcher allowed learners to answer the following question: A stone of mass 6 kg is raised to a height of 10 m and is then allowed to fall freely to the ground. Assuming that g = 10 $m.s^{-2}$, calculate (a) total mechanical energy at the highest point B, halfway through the fall and (b) at ground level, just before the stone struck the ground.

APPENDIX C: DATA ANALYSES

Table 5.5: Frequencies of reasons given by learners in the pre-test

	YES		**NO**	
	Reasons	**Percentage**	**Reasons**	**Percentage**
a)Rock	You can pick it up or throw it	11%	It is not living	18%
	You can build with it	9%	It is not moving	15%
	It is heavy	15%	It does not have energy	7%
	It has sand/ water	15%	We cannot eat it	2%
	Other reasons	4%	other	11%
b)Tree	Gives us food	13%	Does not move	5%
	It has air	11%	It does not have energy	5%
	Gets energy from sun	9%	Other reasons	30%
c)Dog	It can run	22%	It is not strong	7%
	It is living	18%	It is not a human being	11%
	It is an animal	15%	No reason at all	11%
	It has power	11%	Other reasons	4%

	YES		NO	
	Reasons	**Percentage**	**Reasons**	**Percentage**
d)Learner	He/she is living	36%	A learner has energy when he /she use it	2%
	He/she has the ability to do work	18%		
	He/she can eat	18%		
	Other reasons	11%		
e) An apple hanging on a tree	The tree is growing and gives us oxygen	11%	It just hangs on the tree	15%
	It provide us with food	7%	It is not moving	13%
	It is living	7%	It is non living	18%
	Other reasons	4%	No force is needed to take it from the tree	11%
			Other reasons	16%
f) Is energy, power and force the same concepts	You cannot make anything without energy, power and force	18%	They do not perform the same job	2%
	They are all related to work	11%	No reason given	25%
	They are interchangeable	27%		
	Other	16%		

	YES		NO	
	Reasons	**Percentage**	**Reasons**	**Percentage**
g) Non living object like a ball	If it get kicked and start to move	25%	It is not living	33%
	When it is stationary	5%	When a boy plays with a ball he runs and loose energy	22%
	Other reasons	4%	It has no power	7%
			Other reasons	4%
h) Does energy causes motion	Movement of any kind involves energy	22%	Energy it is an occurrence not a cause of motion	11%
	Energy causes something to occur	15%	Motion does not use energy	4%
	Energy is the ability to do work	15%	Energy does not cause motion	4%
	Gives us strength	2%	Other reasons	25
	Other reasons	24%		
i) Does a sleeping dog possess energy?	It is living	18%	It is not doing anything	18%
	It can breath	7%	It is not moving	11%
	It cannot move	11%	All parts are relaxed	11%
	Other reasons	2%	Energy is not used at that moment	7%
			Other reasons	11%

	YES		NO	
	Reasons	**Percentage**	**Reasons**	**Percentage**
j)Does force causes motion	Force causes motion, for work to be done force must be applied	27%	Energy is something that can cause something to move	7%
	We use energy to force something to occur	18%	We do not need force for an object to move	4%
	A wheelbarrow need a force to move	18%	Force is power we use it to make object to move	4%
	Other reasons	9%	Force does not work like energy	5%
			Other reasons	2%
k. Food	We cannot live without food	9%	It only gives us energy when you it	18%
	If we eat we can do any kind of job	2%	Energy is not stored in food	3%
	It gives us body energy	4%	Other reasons	13%
	Nutrients in food	4%		
	It gives us strength	5%		
	It gives us power to do work	7%		

	YES		NO	
	Reasons	**Percentage**	**Reasons**	**Percentage**
1) Fuel	It makes car to move	5%	It is a gas	22%
	It has power	4%	It is not good to human being	20%
	It has energy only on cars not on human beings	4%	We cannot drink it	33%
	It has chemical energy	2%	Other reasons	7%
	Other reasons	3%		