

**EFFECTIVE TEACHING OF CONSERVATION OF
MECHANICAL ENERGY**

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ABSTRACT

The understanding of the scientific meaning of the concept of energy and the principle of the conservation of mechanical energy is affected by various connotations and meanings that the concept and principle have in everyday language use. Young children develop and formulate their own conceptual meanings and understanding of the concepts that often differ from the scientific meanings. These preconceived ideas are termed alternative conceptions of the learners. Learners associate the concept of energy with living and moving objects, in other words, the difficulties experienced by learners in comprehending the scientific concept of energy and its conservation are embedded in their anthropocentric and anthropomorphic views.

Focusing on the nature and origins of these alternative conceptions held by learners, a literature study of contemporary constructivist teaching and learning strategies was conducted. The theoretical investigations led to an empirical study. A quantitative action research methodology was undertaken. Firstly, a questionnaire was designed and administered to grade 10 learners to diagnose their alternative conceptions about the concept of energy and the principle of conservation of energy. The results of the questionnaire were analyzed to determine the nature of the alternative conceptions held by the learners.

Secondly, an intervention program was designed. During the intervention various factors that might contribute to learners' conceptualization of the concept of energy were exploited. Contemporary teaching-learning approaches and strategies, which are constructivist in nature, were used. Inquiry teaching was implemented through the 5E instructional model. The teaching and learning experiences were contextualized, i.e., they were designed using situations and experiences that were familiar to the learners.

Thirdly, the success of the intervention to accomplish conceptual change was assessed. The analysis of the results of the empirical study shows a significant improvement of the learners' understanding of energy and its conservation. This was reflected in the calculated normalized learning gain of 68%. The results show the importance for teachers to continuously do active research on various aspects of the

educational environment like learners' alternative conceptions, contemporary teaching-learning strategies and contextual factors that might influence effective teaching and learning.

UITTREKSEL

Die verstaan van die wetenskaplike betekenis van die konsep van energie en die beginsel van die behoud van meganiese energie word beïnvloed deur verskeie konnotasies en betekenis wat die konsepte in alledaagse taalgebruik het. Jong kinders ontwikkel en formuleer hul eie konseptuele betekenis en begrip van die konsepte wat dikwels verskil van die wetenskaplike betekenis. Hierdie vooropgestelde idees word alternatiewe opvattinge van leerders genoem. Leerders assosieer die konsep van energie met lewende en bewegende voorwerpe, met ander woorde, die probleem wat die leerders met die verstaan van die wetenskaplike konsep van energie en die behoud daarvan ondervind is in hulle antroposentriese en antropomorfe sienings vasgelê.

Deur te fokus op die aard en oorsprong van hierdie alternatiewe opvattinge wat leerders koester, is 'n literatuurstudie oor kontemporêre konstruktiewe onderwys- en leerstrategieë gedoen. Die teoretiese ondersoek het tot 'n empiriese studie gelei. 'n Kwantitatiewe aksienavorsing metodologie is aangepak. Eerstens is 'n vraelys ontwerp en aan graad 10 leerders gegee om hulle alternatiewe opvattinge oor die konsep van energie en die beginsel van behoud van energie te diagnoseer. Die resultate van die vraelys is geanaliseer om die aard van die alternatiewe opvattinge wat deur die leerders gekoester word te bepaal.

Tweedens is 'n intervensieprogram ontwerp. Gedurende die intervensie is verskeie faktore wat dalk 'n bydra kon lewer tot die leerders se konseptualisering van die konsep van energie ontgin. Kontemporêre onderwys-leerstrategieë wat konstruktief van aard was, is gebruik. Ondersoekende onderwys is deur die 5E instruksiemodel geïmplementeer. Die onderwys en leer ervarings is gekontekstualiseer, dit is, hulle is ontwerp deur gebruik te maak van situasies en ervarings waarmee die leerders vertrou was.

Derdens is die sukses van die intervensie om konseptuele verandering by leerders te bewerkstellig geëvalueer. Die analise van die resultate van die empiriese studie wys 'n betekenisvolle verbetering van die leerders se begrip van energie en die behoud daarvan. Dit word weerspieël in die berekende genormaliseerde leerwinst van 68%.

Die resultate wys op die belangrikheid vir onderwysers om voortdurend aktiewe navorsing oor verskeie aspekte van die onderwysomgewing, soos leerders se alternatiewe opvattinge, kontemporêre onderwys-leerstrategieë en kontekstuele faktore wat effektiewe onderwys en leer beïnvloed, te doen.

ABBREVIATIONS AND NOTES

Terminology

The term

- *Form* as used in the study to identify energy kinds mean a particular way in which energy appears or exist, that is either as kinetic or potential energy.

- *Energy type* then refers to types of energy with similar qualities that make them different from other types. For example, types of potential energy like chemical, elastic, gravitational, etc.

Abbreviations

- OBE – Outcomes Based Education.
- NCS- National Curriculum Statement.
- FET - Further Education and Training.
- GET- General Education and Training
- SASA- South African Schools Act.
- DOE- Department of Education.
- APO- Area Project Office.
- LOLT- Language of Learning and Teaching.
- LO- Learning Outcome.
- RSA- Republic of South Africa

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CHAPTER 1

ORIENTATIVE INTRODUCTION.

1.1 Problem statement and motivation.

The concepts of energy and conservation of energy are abstract, but more importantly, are fundamental and central in science as well as other subjects (e.g. technology, humanities, etc.) (Hewitt, 2002:104; Boyes & Stanisstreet, 1990:51). This study focuses on learners' conceptual understanding of concepts relating to the principle of conservation of mechanical energy (in a closed system). Mechanical energy is the form of energy due to the relative position of interacting objects (potential energy) or due to their motion (kinetic energy) or both (Hewitt, 2002:106-107). The concept of mechanical energy is useful in describing motion (Cutnell & Johnson, 2004:159), i.e. in the study of kinematics.

More important than being able to state what energy is, is to understand how it behaves, i.e. how it transforms (Hewitt, 2002:111). Processes in nature can be understood when analysed in terms of energy changes. The study of various forms of energy and their transformations has led to one of the greatest generalizations in physics, namely the principle of conservation of energy. This principle can be formulated by the following: energy cannot be created or destroyed. It may be changed from one form into another, but the total amount of energy never changes.

Research studies show that even if learners receive formal instruction on concepts such as energy they still harbour, adhere to and hold firmly onto their alternative conceptions (Zain & Sulaiman, 1998; Rankhumise & Lemmer, 2008). This could have been brought about by the use of traditional teaching and learning strategies which are teacher centred and whereby the learner is the passive recipient of information and knowledge (Bybee, 2002). It is difficult for a teacher to change learners' alternative conceptions about any particular concept in formal teaching. For better understanding of scientifically correct concepts, it is essential that a

combination of a variety of constructivist teaching and learning approaches are used (Trumper, 1991:6; Trowbridge *et al*, 2000:224; Scott *et al*, 1991:7).

The constructivist teaching-learning theory is at present the most frequently used theory associated with human learning worldwide (Trumper, 1991:6). According to the constructivism principle, individual learners build their knowledge by making connections to existing knowledge (Redish, 2003). The principle of constructivism applied to the teaching and learning environment is embraced and contained in the OBE (Outcomes Based Education) principles that form the foundation for curriculum reform in South Africa (Department of Education, 2003). As a teaching and learning theory, constructivism can be implemented using strategies such as problem-solving and inquiry strategies (Gunter *et al*, 1991).

The constructivist approach to teaching and learning also emphasizes the organization of the learning content within a context that learners find familiar and best relate to their experiences (Bybee, 2002:9; Osborne & Dillon, 2007:1441-1442; Bennet *et al*, 2006:348, Stears *et al*, 2003:109). The consideration of contextualized learning content advocates the relevance and applicability of what is learnt in school to the real life world. It also helps learners recognize and appreciate the use of concepts and the meaning of concepts in the real life world and scientific contexts.

The problem attended to in this study is how to treat and handle learners' alternative conceptions relating to the principle of conservation of mechanical energy. The study investigates the effectiveness of an inquiry teaching-learning sequence aimed to remedy alternative conceptions that learners have relating to mechanical energy and the conservation thereof. The focus is on Grade 10 learners, because Grade 10 learners are introduced to the Further Education and Training (FET) level in which the concepts are formalized. Conceptual understandings of these concepts are vital before formalization (Lemmer & Lemmer, 2005).

The teaching-learning sequence compiled and implemented in this study follows the design principles of progression and integration in the implementation of the OBE curriculum

(Nieuwoudt & Beckley, 2008:324-328). The progression principle enables learners to gradually develop more complex, deeper and broader knowledge, skills and understanding. The integration principle requires learners to apply their knowledge and skills in other contexts. In this study learners were required to integrate their classroom knowledge with everyday experiences.

1.2 Aims.

The aim of the research study is to investigate the effectiveness of an inquiry-based teaching-learning sequence that aims to improve Grade 10 learners' understanding of concepts relating to the principle of conservation of mechanical energy (in a closed system) and that adheres to the OBE principles of progression and integration.

1.3 Hypothesis.

Alternative conceptions of concepts relating to the principle of conservation of mechanical energy that are found amongst Grade 10 learners can be remedied effectively by means of an inquiry-based teaching-learning sequence that adheres to the OBE principles of progression and integration.

1.4 Target population.

An action research study (paragraph 4.2.1) was conducted with a class of thirty-seven Grade 10 learners (eighteen girls and nineteen boys). The learners are enrolled at Bakolobeng High School (Ganalaagte - Ganapan-cluster in the Greater Delareyville APO). Ganalaagte is one of the impoverished villages in the North West province in the Tswaing Municipality - Central region. The preferred as well as the first language of the learners is Setswana. English is used as a second language as well as the language of learning and teaching (LOLT).

1.5 Research method.

1.5.1 Literature study.

Through a literature study (Chapter 2) alternative conceptions relating to the principle of conservation of mechanical energy are reviewed. Attention is also given to contemporary teaching and learning strategies that are in accordance with requirements stated in the NCS (Department of Education, 2003) and that could be used to enhance conceptual change in learners (Chapter 3). Study material was obtained from the library through, for example, screening of recent publications in scientific and educational journals and books. The following key words are used: mechanical energy, kinetic energy, potential energy, conservation of energy, alternative conceptions, constructivism, inquiry and contextual teaching.

1.5.2 Empirical study.

An empirical study was conducted to determine and remedy alternative conceptions that Grade 10 learners have regarding concepts relating to the principle of conservation of mechanical energy. The empirical study consists of a pre-test, intervention and post-test.

- Pre-test: A questionnaire was prepared and administered to diagnose the alternative conceptions held by learners.
- Intervention: Inquiry teaching-learning activities and lessons were designed and presented to learners in order to enhance understanding and promote conceptual change of concepts relating to the principle of conservation of mechanical energy. The contextualized approach involved laboratory and everyday experiences.
- Post-test: The same questionnaire as for the pre-test was used for the post-test. The average normalized gain is calculated to indicate the effectiveness of the intervention.

The empirical study is described in detail in Chapter 4.

1.6 Data processing.

A statistical analysis is performed on the results of the pre- and post-tests. Normalized learning gains are calculated to determine the achievements of the inquiry-based teaching-learning sequence. The results are given and discussed in Chapter 5. Chapter 6 gives an overview of the study with the conclusions and recommendations made after the results have been evaluated and analysed.

1.7 Highlights of the chapters.

Chapter 1- Orientative introduction.

Chapter 1 offers an introduction to the study. The research problem is identified and motivated. The aims, hypothesis, target population and research methods are discussed.

Chapter 2- Literature review on learners' alternative conceptions of the concepts relating to the conservation of mechanical energy.

Chapter 2 provides a literature review on the nature, origins and educational implications of learners' alternative conceptions relating to the principle of conservation of mechanical energy. The literature review informs the compilation of the questionnaire used in the empirical study.

Chapter 3- Literature review of contemporary teaching-learning strategies.

Chapter 3 offers a literature review on constructivist teaching-learning strategies, which can be used to build on, construct or reform learners' alternative conceptions. The intervention applies strategies described in Chapter 3.

Chapter 4- Empirical study.

The research design and methodology of the empirical study are discussed in Chapter 4. This includes the study population, instruments of the research as well as a classification and

discussion of the questions in the questionnaire and how it is used to evaluate the effectiveness of the intervention.

Chapter 5- Results and analysis of the results.

Chapter 5 deals with the data collected and analysed in the empirical study. General problems that learners have with concepts relating to the conservation of mechanical energy are identified. The pre- and post-test results and the normalized gains are given and discussed.

Chapter 6- Summary, conclusions and recommendations.

Chapter 6 offers the conclusions of the research study as well as suggestions for further research.

1.8 Significance of the study.

Learners harbour and adhere to their alternative conceptions even if scientific concepts are presented during formal teaching. Firstly, research in this field enhances our knowledge of how to address this problem by providing practicing teachers in South African schools with ways of finding out about the nature of these conceptions held by their learners.

Secondly, teachers should research their own practices. One of the seven roles of a teacher identified by the Department of Education is that he/she should be a scholar, researcher and life-long learner (Vakalisa, 2008:24). Through this study, teachers should be able to adapt and apply contemporary teaching strategies and approaches that will promote and enhance constructive and effective learning by the learners.

Thirdly, the results of this study can contribute to international research, since it addresses learners' problems with concepts that were found to be difficult for learners worldwide.

CHAPTER 2

LITERATURE REVIEW: LEARNERS' ALTERNATIVE CONCEPTIONS RELATING TO THE CONSERVATION OF MECHANICAL ENERGY.

2.1 Introduction.

The word 'energy' is often used fairly loosely in and out of the science classroom. It is a very difficult scientific concept to define satisfactorily (Hewitt, 2002:104). Energy is a theory-loaded concept that can be best understood within the framework of its related concepts, laws and supportive theories (Sexl, 1981:293-294). In everyday life, the idea of obtaining energy from fuels or food is familiar and it is a general idea to consider fuels (including food) as stores of usable energy from which proportions of energy can be withdrawn (Friedl, 1991:283). Energy taken from fuels (e.g. petrol for cars) enables useful tasks to be performed (e.g. transport). These everyday-life ideas should be expanded or refined towards an understanding of the scientific concepts (Lemmer & Lemmer, 2008; Trumper, 1990).

Learners often regard energy as anthropomorphic and anthropocentric (Watt, 1983:214). Children tend to consider non-living objects as being alive and energy as the property of only living and moving objects. These and other problems that learners have in studying the concept of energy and the principle of conservation of energy are discussed in paragraphs 2.3 and 2.4. This chapter starts with the scientific view of energy and its related concepts (see paragraph 2.2).

2.2 Energy and related concepts in science.

2.1.1 Scientific definition of energy.

In most science textbooks the concept of energy is defined as ‘the ability to do work’ (Dilley *et al.*, 2005:46; Heyns *et al.*, 2002:64; Kotz & Treichel, 1996:258; Smith *et al.*, 2007:26; Kelder *et al.*, 2007:45).

In science emphasis is placed on what the concept means and what its effects on matter and materials are, both at macroscopic and sub-microscopic level. Every change that occurs in nature, either a chemical or physical change involves energy. In defining the concept of energy, three important aspects of energy are recognized (Reynolds, 1974:5; McIldowie, 1995:229; Brookes *et al.*, 2006:37), namely:

- All material objects have energy (energy is a property of matter and materials).
- Energy of the whole is the sum of energies of the parts.
- Energy is conserved, that is, energy of the whole system remains constant.

These three ideas are as fundamental as energy itself (Reynolds, 1974:5). Matter and materials possess energy as the result of their motion or position in relation to forces acting on them (Trumper, 1990:208-209). If a body has energy, it can exert a force to move something over a distance, i.e., it can do work. It must be noted that this explains what energy does (effect) and not what it is (Reynolds, 1974:37).

All forms of energy are associated with motion; for example, any given body has energy (kinetic energy) if it is in motion. A tensioned device such as a spring or elastic rubber, though at rest, has the potential for creating motion (potential energy) because of its configuration (Watt, 1983:213-216; Ogunniyi & Taale, 2004:83).

2.2.2 Concept of work.

Work, like energy, also has a specific meaning in science. Work (W) is defined operationally as the product of the force (F) applied to a body and the displacement (s) of the body in the direction of the applied force ($W = F \cdot s \cdot \cos\theta$). When a force does work on an object, it means that some energy is transferred from the object producing the force to the object that moves. Work is then the amount of energy transferred (Reynolds, 1974:37; Hewitt, 2002:105). This

provides a quantitative measure of energy and is the existential definition of work. These two concepts (work and energy) are related since work is energy transferred from the source to the object or system and is measured with the same unit, which is the joule (Legge & Petrollito, 2003:436-437).

2.2.3. Forms of energy.

There are many different types of energy, but all are kinds of either kinetic (E_k) or potential (E_p) energy (Long, 2000:91; Grayson *et al*, 2005:99). Some of the more familiar types of energy are:

- Electrical energy – (energy of moving charged particles).
- Heat energy – (energy in transit from a hot to a cold body).
- Light energy – (energy carried by photons of light).
- Sound energy – (energy of a vibrating medium).
- Chemical energy – (energy that brings about changes in chemical substances).
- Nuclear energy – (energy associated with the fusion or splitting of nuclei).
- Mechanical energy – (energy associated with the motion and position of an object).

2.2.3.1 Kinetic energy (E_k).

By definition, kinetic energy is the energy form that an object has by virtue of its motion. Kinetic energy is a property of a moving object or particle and depends not only on its speed, but also on its mass. The kind of motion may be along a path from one place to another, rotation about an axis, vibration or any combination of motions (Kotz & Treichel, 1996:18). Translation kinetic energy of a body is equal to the product of one half of its mass, m , and the square of its velocity, v , or in symbols $E_k = \frac{1}{2}mv^2$ (Cutnell & Johnson, 2004:157).

If work (W) is done on an object by applying a net force, energy is transferred. The object speeds up and thereby gains kinetic energy (ΔE_k) which can be calculated with the work-kinetic energy theory: $W = \Delta E_k$ (Cutnell & Johnson, 2004:159; Smith *et al*, 2007:26).

2.2.3.2 Potential energy (E_p).

Potential energy depends upon the relative position of various parts of a system. For example, a spring has more potential energy when it is compressed or extended than when it is relaxed. A steel ball has more potential energy when raised above the ground than it has after falling to the earth, because at the raised position the steel ball is capable of doing more work. Potential energy is thus a property of a system and not of an individual body or particle (Kotz & Treichel, 1996:258-259; Smith *et al*, 2007:27-28).

Potential energy arises in systems with parts that exert forces on each other. There are a number of different types of potential energy; each energy type is associated with a particular type of force. For example, in the case of the *earth-ball* system, the force of gravity between the two depends on the distance separating them. The work done in separating them further, or in raising the ball, transfers additional energy to the system. The energy transferred to the system is stored as gravitational potential energy (Kotz & Treichel, 1996:258-259).

Gravitational potential energy near the Earth's surface may be calculated by multiplying the weight (mg) of an object by its distance (h) above a reference point or position, i.e., $E_p = mgh$ (Kotz & Treichel, 1996:558-559; Reynolds, 1974:6-7; Smith *et al*, 2007:27).

Chemical and electrical potential energies are potential energies subject to Coulomb force (attractive or repulsive force). During chemical reactions, Coulomb force causes the rearrangement and movement of electrons, nuclei or ions of atoms, molecules or compounds. In chemical reactions, potential energy of substances can be transformed to other types of energy forms like heat. Electrical potential energy is energy that an object possesses by virtue of electric charge and the presence of electric forces. For example, to move a charge within an electric field, an electric force is exerted on the charge and hence by moving it, the potential energy of the charge is converted to kinetic energy (Heyns *et al*, 2002:91 & 157-158).

School science textbooks often describe potential energy as being stored in a system. This provides a quasi-material conception of energy. Duit (1981) and Kaper & Goedhart (2002) argue that this concept of energy can form part of a consistent, valid intermediate language for

use in education. It can be used to describe and predict phenomena in a certain limited domain of experiences.

2.2.4 Energy changes and the law of conservation of mechanical energy.

When energy is transformed from one form to another (in a closed system), no energy is lost in the process (Cutnell & Johnson, 2004:167). The observation that the total of all energies before and after a process is equal, leads to the principle of conservation of energy, namely that energy can neither be created nor destroyed, but can only be converted from one form to another.

Mechanical energy is the sum of the kinetic energy and gravitational potential energy of a system ($E_{total} = E_k + E_p$). The principle of conservation of mechanical energy states that the total mechanical energy in a closed system remains constant. A closed system is a system lacking dissipative forces, such as friction and/or air resistance, or a system in which such forces can be reasonably neglected (Kotz & Treichel, 1996:259-260; Reynolds, 1974:5-10; Kelder *et al*, 2007:45; Brookes *et al*, 2006:40).

The pendulum is an example of the conservation of mechanical energy that is often used. A swinging pendulum has its greatest kinetic energy and lowest potential energy in the vertical position. In this position the speed of the pendulum is maximum and the height above the earth is the least. It has its lowest kinetic energy and greatest potential energy at the extremities of its swing. The speed at the extremities of its swing is minimum and the height is greatest. As the pendulum swings, energy is continuously changing back and forth between the two forms (kinetic and potential energy). Neglecting friction at the pivot and air resistance, the sum of kinetic and potential energy of the pendulum (mechanical energy) is constant.

The principle of conservation of mechanical energy offers a keen understanding of ways in which the physical universe operates (Cutnell & Johnson, 2004:161). For example, the mechanical energy of the Earth-moon system is nearly constant as it rhythmically interchanges

between its kinetic and potential energy forms (Heyns *et al*, 2002:67-68; Kotz & Treichel, 1996:257-260).

2.3. Alternative conceptions in science.

2.3.1 What are alternative conceptions of learners?

Alternative conceptions of learners are unscientific views and ideas of the world and meanings of words that learners have acquired and bring to science classes. These ideas and views are considered by learners to be sensible and more useful than those presented to them by teachers from a scientific point of view (Osborne & Freyberg, 1995:6-7; Ogunniyi & Taale, 2004:77). These ideas held by learners are coherent and strongly adhered to. If not diagnosed and treated they have a significant negative impact on the learners' learning.

2.3.2 Origins of learners' alternative conceptions.

Young children introduce themselves to the world of substances and experiences as they explore the environment through many and varied experiences using their senses well before their language develops. For example, children test qualities and properties of things through tasting, feeling, smelling, and observing. When their language starts to develop, they attach meaning to a large number of words and formulate ideas and views for daily phenomena (Osborne & Freyberg, 1995:8; Ogunniyi & Taale, 2004:77, Tsai & Chang, 2005:1089-1090; Zain & Sulaiman, 1998:415). Words and views about phenomena, which have specific, special and agreed meanings in a scientific context, might have significantly different meanings for learners. This forms a basis for the formation of learners' alternative conceptions.

Alternative conceptions of learners in the science class could be termed 'child science', because a child (prior to formal instruction) has already formulated ideas or views about a particular scientific concept (Watt, 1983:213). As a result, the interaction between the meanings for words, ideas and views about a concept held by learners and the meanings

presented by the teacher in a science class affect learners' learning (Osborne & Freyberg, 1995:8).

From a scientific point of view, work as a concept has the meaning of energy expenditure. But in everyday life, work is associated with labour. This is an example of a mismatch of words and different meanings for the same word when used in different contexts. As already discussed in paragraph 2.3.1 this mismatch may present a problem for learners in learning a correct scientific meaning for the concept (Osborne & Freyberg, 1995:34). For example, it can become difficult to convince learners that more work is being done when playing soccer for an hour than when studying for two hours in preparation for exams.

According to Ogunniyi and Taale (2004:84-85), language is a medium and vehicle through which a child interacts with the environment. Language plays a pivotal and important role in children's formation of meanings for words or views of concepts and phenomena (Kabapinar *et al*, 2004:636; Wesi, 2003:248). For example, when learners are asked to explain things, they have to do this in their own words. The explanations and interpretations are often found to be in contrast or disagreement with the accepted scientific meaning and understanding. Further explanations given by learners for a situation or concept might reflect that the disagreement is not influenced by lack of understanding, but by different meanings attached to the terms used. This may cause conceptual problems as is shown in the following paragraphs (paragraph 2.4 and 2.5) with relation to the concept of energy.

2.4 Learners' alternative meanings attached to concepts.

The law of conservation of energy is often confused with the everyday language use of the words "law" and "conservation" (Boyes & Stanisstreet, 1990:51; Wesi, 2003:248). For example, the word "law" is understood by children from everyday language use as a prohibiting statement of which, when contravened, the results are negative. In science the word is understood and interpreted as either a formula or as behaviour of natural phenomena within certain confines and conditions.

Conservation of energy is thought of or talked about as the wise and useful use of energy resources, i.e., to use energy more efficiently and not to waste it. Scientifically, conservation of energy involves energy changes into different forms. Although some forms like heat, sound and light may be less useful, the total amount of energy remains constant (Kotz & Treichel, 1996:162; Boyes & Stanistreet, 1990:51; Wesi, 2003:248).

2.5. Alternative conceptions regarding mechanical energy and its conservation.

In mechanics, the most common alternative conceptions held by learners regarding the concept of energy and energy conservation are anthropocentric and anthropomorphic in nature (Trumper, 1991). Energy is mainly associated with moving and living things. For example, learners will agree that a person walking up-hill has energy obtained from food (fuel) as much as the tractor pulling a trailer up-hill has energy obtained from the fuel it uses. But they will think that a tractor that is stationary on an inclined plane does not possess energy because it is neither living nor moving. The following alternative conceptions relating to the concept of mechanical energy may be displayed by both learners and teachers (Watt, 1983:214-216; Wesi, 2003:260; Rankhumise, 2008; Lemmer, 2008):

Interchangeable terms and the relation between energy and other concepts.

- The terms “energy”, “force” and “power” are used interchangeably and in some instances might mean the same thing.
- The word “work” is synonymous with labour from everyday language use, experiences and observations.
- Energy conservation means wise use or taking good care of energy.
- The statement “law of conservation of energy” is confused with statutory laws, which have prohibiting statements.

Energy is associated with living things and motion.

- An object at rest has no energy.
- A non-living object has no energy.

Energy expenditure (energy is used up).

- Objects use up energy; for example, a car that has run out of petrol has used up its energy.
- A person who is tired after hard work has used up his or her energy.

Energy is a fuel.

- Energy is considered as material that can be used for essential tasks or something that can propel other objects, e.g. fuels (like petrol, paraffin, diesel, etc) and electricity.

Problems relating to the concept of potential energy.

- Learners think that objects at rest cannot have any energy.
- Gravitational potential energy is perceived to only depend on the height of an object above a chosen reference level.

Problems relating to the conservation of mechanical energy.

- According to everyday experiences, we can “run out of energy”.
- Energy is lost in energy transformations.
- Different amounts of energy are used when pushing or pulling a cart up a hill of the same height.

2.6 Educational implications.

According to Meheut and Psillos (2004:515) and Meltzer (2002:1259-161), it is important to find out about and recognize alternative conceptions that learners bring to science classes prior to formal instruction. This follows from the constructivist theory of learning (discussed in paragraph 3.3.1). The essence or interest of teaching and learning science emphasis improved learners’ understanding of scientific knowledge and their participation in science related fields once they leave formal schooling (Roth & McGinn, 1998:213; Ogunniyi & Taale, 2004:77).

2.7. Summary.

A fundamental aim of research in science education is to find variables or factors that might be obstacles to learners' effective learning of scientific concepts. Once identified, the learning obstacles need to be addressed in such a way as to enhance effective learning. The next chapter deals with a literature review of contemporary teaching - learning strategies that can improve meaningful and effective teaching and learning of the concept of energy and the principle of conservation of energy. The underlying principles and applications of these strategies are discussed.

CHAPTER 3

CURRICULUM ANALYSIS AND CONTEMPORARY TEACHING-LEARNING STRATEGIES.

3.1 Introduction.

The constructivist teaching–learning theory (paragraph 3.3) suggests that the teacher has to play an important role to facilitate learners’ conceptual change (Scott *et al.*, 1991:5-10; Scholtz & Amosun, 2004:41-42). The teacher has to do the following (Department of Education, 2003):

- Act as a diagnostician, i.e., to diagnose learners’ alternative conceptions prior to formal presentation and also elicit them.
- Act as a learning mediator, i.e., be able to recognize learners’ individual needs and how they learn.
- Develop strategies that will enable him/her to deal with these alternative conceptions held by learners.
- Be a scholar, researcher and lifelong learner by keeping up to date with new developments in the discipline and profession.
- Develop evaluation techniques, which take into account how learners solve problems and also to what extent they grasp and understand scientific concepts.

All these have to be done within the frameworks of the new curriculum statements, which are discussed in the next paragraph 3.2. Contemporary teaching strategies that are in line with the curriculum statements and based on constructivism are discussed in paragraph 3.3.

3.2. National curriculum statement.

3.2.1. Curriculum analysis.

Considering the new curriculum (Department of Education, 2003), teaching the energy concept and the principle of conservation fits well in the general education and training band (GET). The band starts from grade four and proceeds to grade nine (grade 4-9). In this band, the core knowledge of the concept of energy and energy changes are found in the knowledge area called *Energy transfers and systems* (Department of Education, 2002:66). In this knowledge area learners are introduced to various sources of energy and benefits of different energy forms that are required to meet and cater for our daily needs and services (qualitative aspect of energy). The concept of energy is thus gradually developed in this band.

Given the level of learners' development, this is the band in which learners' alternative conceptions are prevalent. Therefore, this is the band that provides a convenient platform to teach learners conceptual change (Zain & Sulaiman, 1998:415). The strategies and approaches to be used in this band (GET) must be constructive in the sense that learners must be active and purposeful during the learning process. Learners must also be actively involved in bringing prior knowledge to bear in order to construct meanings in new situations (Trumper, 1991:2-3).

In the further education and training (FET) band that ranges from grade ten to twelve (grade 10-12), learners may still have alternative conceptions about the concept of energy (Rankhumise & Lemmer, 2008). The concept of energy under the knowledge area *Mechanics* is treated and defined more formally because of its quantitative nature.

The outlined learning outcomes (LO) of physical science (Department of Education, 2003:13-14) are:

LO 1-Practical science inquiry and problem solving skills.

LO 2-Construction and application of scientific technological knowledge.

LO 3-Science, society and environmental issues.

Assessment standards for each learning outcome are also stated in the NCS (Department of Education, 2003). The following examples are given:

Assessment standards (AS) for LO 1 are:

- Conducting an investigation.
- Interpreting data to draw a conclusion.
- Solving problems.
- Communicating and presenting data and scientific arguments.

Assessment standards (AS) for LO 2 are:

- Recalling and stating specified concepts.
- Indicating and explaining relationships.
- Applying scientific knowledge.

Assessment standards for LO 3 are:

- Evaluating knowledge claims and science's inability to stand in isolation from other fields.
- Evaluating the impact of science on human development.
- Evaluating science impact on environmental and sustainable development.

These assessment standards provide guidelines for designing and planning activities for learning experiences that promote effective teaching of concepts such as energy and the conservation of energy in mechanics for grade 10 to 12 learners in the context of OBE (Department of Education, 2003).

The new curriculum for South Africa through the principle of OBE, confirms the assumption that teaching and learning involve interactions between new conceptions and pre-knowledge. As stated by Trumper (1991:2-6) a curriculum has to be considered as a process in which learners are actively involved in constructing a view of the world closer to the scientific views.

This view relates to the principle of progression stated in the NCS (Department of Education, 2003).

3.2.2 Content and context in the NCS.

The contexts from which learning experiences, such as the gathering of information and the processing of it in tables and graphs, are designed play an essential role in the teaching and learning process. They are not to be thought of as only science activities that form part of the learning process, but as a translation from context to solve daily problems. The content standards of the curriculum should illustrate important features such as emphasis on major ideas, links to meaningful experiences, concepts, applications and generalizations that are developmentally appropriate for the learner (Gunter *et al*, 1991:43).

The table 3.1 below offers an overview on how the concept of energy and conservation of mechanical energy has been organized and ordered in the curriculum of South Africa (Department of Education, 2003:39 & 51). The ordering and organizing of the content in this way offers directives and guidelines on how the content can be structured and taught using a variety of contexts which learners find familiar.

TABLE 3.1. Content and context in the NCS (Department of Education, 2003).

Core knowledge	Mechanics		
	Grade 10	Grade 11	Grade 12
Content	<ul style="list-style-type: none"> ➤ Motion in one dimension. ➤ Gravity and mechanical energy. 	<ul style="list-style-type: none"> ➤ Force, momentum and impulse. 	<ul style="list-style-type: none"> ➤ Motion in two dimensions. ➤ Work, energy and power.
Possible context	<ul style="list-style-type: none"> ➤ Transportation. ➤ Planets and their movement. 	<ul style="list-style-type: none"> ➤ Transportation. ➤ Movement ➤ Astronomy, 	<ul style="list-style-type: none"> ➤ Transportation. ➤ Planets and their

	<ul style="list-style-type: none"> ➤ Astronomy, cosmology. ➤ Machines and mechanics. ➤ Structures. ➤ Weather systems. 	<ul style="list-style-type: none"> cosmology. ➤ Road accidents. ➤ Structures. 	<ul style="list-style-type: none"> movement. ➤ Astronomy, cosmology. ➤ Structures. ➤ Weather systems.
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Content progression.

The meaningful organization of the content would support understanding and make sense of the experiences of the learners. This begins with informal ideas that learners bring to the science class in the lower grades (grade 4-9) and gradually helps the learners to develop and maybe reform those ideas into formal science concepts in the upper grades, for example, grade 10-12 (Department of Education, 2002:66, Department of Education, 2003:13-14).

The content of the curriculum of South Africa (C2005) has been organized in such a way as to help learners to build scientific understanding and abilities of inquiry in gradual and structured ways during their schooling. The organization of content in this way gives learners opportunities to confront and reconstruct their alternative conceptions (Bybee, 2002:15).

Context integration.

Learning occurs informally prior to formal instruction in class. The school as an institution of formal instruction should recognize, enhance and build on what has already been learnt informally from social and cultural context. Learning and the application of scientific ideas by using familiar contexts (context infused content) as a starting point for the development of the scientific ideas help and encourage learners to make sense of a situation. The contextualised learning experiences can also help learners engage and work with science problems and form concepts in a meaningful way (Bennet *et al*, 2006:348-349; Stears *et al*, 2003:109; Osborne & Dillon, 2007:1441; Bricker, 2005:14).

Linking learners' science learning to their everyday knowledge drawn from familiar contexts has the following outcomes and benefits:

- Provides learners with practicality and applicability of scientific concepts and ideas in real life situations.
- Builds on their experiences, interests and prior knowledge (constructivist view and approach).
- Motivates learners.

3.2.3 Progression principle of OBE.

Progression as one of the key principles in the design of the new curriculum (C2005) of South Africa, refers to the process of developing more advanced, complex, deeper and broader knowledge skills and comprehension (Department of Education, 2003: 87; Department of Education, 2002: 3). This progress should take place in each grade for a particular learning content area and across the bands or phases, that is the GET band (grade 7-9) and FET band (grade 10-12).

The progression within a specific learning content area in the band is guided by the provision and availability of suggested contexts as discussed in paragraph 3.2.2. The learning content is graded and organised by virtue of its complexity and level of cognitive development of the learners (Department of Education, 2002: 45). Each learning outcome to be achieved for core knowledge areas and concepts for natural sciences in the GET band (Department of Education, 2002: 48-59) and physical sciences in the FET band (Department of Education, 2003: 36-39,50-51) is supported by assessment standards.

The scope of concepts relating to the principle of conservation of energy in the GET and FET bands depicts the proposed and expected implementation of the progression principle (Department of Education, 2002:87; Department of Education, 2003:3). Under the core knowledge area energy and change in the GET band the focus is mainly on the conceptual understanding and applications of the energy concept (see paragraph 3.2). But in the FET band the scope is broadened in each grade (from grade 10 to 12). Both the qualitative and

quantitative aspects of energy are treated in the FET band as well as the principle of conservation of energy. A variety of possible contexts through which the concepts relating to the principle of conservation of energy could be delivered and taught are suggested in the NCS (Department of Education, 2003: 36-39; 50-51).

3.2.4 .The teacher's role in OBE.

Teaching for conceptual change and greater scientific understanding requires a teacher to systematically design teaching and learning approaches which will diagnose and remedy learners' alternative conceptions (Scott *et al.*, 1991:1-2; Department of Education, 2003:5). The following approaches should be considered when teaching for conceptual change using an integrated teaching and learning model:

- Identify the learners' alternative conceptions.
- Challenge the adequacy of alternative conceptions.
- Introduce scientific concepts that are plausible, intelligible and helpful.
- Provide opportunities to apply new ideas in a familiar context.

These approaches are explicitly outlined in the policy document for physical science, grade 10-12 (Department of Education, 2003:10-11). Some contemporary teaching strategies that adhere to these requirements are discussed in the next section (paragraph 3.3).

3.3. Contemporary teaching strategies.

3.3.1 Constructivism.

A constructivist approach to teaching and learning acknowledges and recognizes the existence of learners' pre-knowledge prior to formal teaching and learning experiences. This pre-knowledge is actively applied by learners in responding and making sense to new situations (Watt, 1983:214-216; Fraser & Tobin, 2003:349-250).

To overcome deficiencies in learners' pre-knowledge, teachers are faced with the problem of devising different and better teaching and learning strategies that will enhance science learning.

According to Scholtz and Amuson (2004:41-42), constructivism as a contemporary teaching and learning theory is the approach to be implemented in science teaching and learning. It recognizes the following aspects or principles of human learning (Watt, 1983:214-216; Department of Education, 2003:2; Zain & Sulaiman, 1998:45; Scholtz & Amuson, 2004 41-42):

- Learning is an interaction of ideas and processes.
- Learning is active.
- Learning is augmented in social interaction.
- New knowledge is built on prior knowledge.
- Learning is enhanced in situations and contexts that learners find familiar and meaningful.
- Complex problems that have multiple solutions and social interactions enhance learning.
- Learning is basic, because since early life children attempt to make sense of their world from explanations of phenomena. This then forms a basis for alternative conception formation as opposed to scientific enquiry.
- Learning originates from diverse experiences, because some of the alternative conceptions learners have originate from daily experiences and observations outside the domain of formal instruction. When these explanations are compared with scientific understanding, they are often incomplete, inadequate and inappropriate.

As a teaching and learning approach, constructivism can enable the teacher to elicit and handle learners' alternative conceptions (Trowbridge *et al*, 2004:154) for example, about the concepts relating to conservation of mechanical energy (paragraph 2.2). A combination of various teaching strategies is needed for conceptual change (Trumper, 1991:2-6). According to Trowbridge *et al* (2004:222-224) the inquiry teaching strategy may bring about conceptual change in learners' minds more effectively and more permanently if used effectively and in conjunction with other methods. In the intervention of this study (paragraph 4.6), inquiry teaching and learning is used in conjunction with the lecture based and direct instruction models. These models are discussed in the following paragraphs (3.3.2, 3.3.3 and 3.3.4).

3.3.2. Inquiry teaching strategy.

The inquiry teaching-learning strategy is not only confined within the limits of science teaching and learning. Inquiry is used in other areas of human learning such as social problems, politics, mathematics, literature, history and others. The inquiry teaching and learning strategy depicts the process through which human beings seek information and understanding through processes such as observations, experiments and experiences, which result in empirical evidence about the natural world. When learners study science using inquiry they employ many different skills (e.g. physical and intellectual skills).

Through inquiry the inquisitive nature of the learners is nurtured and they (learners) become motivated and interested in what they are doing. Once interested, the learners acquire cognitive skills and knowledge, and an increase in positive attitudes towards science learning is developed (Gunter *et al*, 1991:43; Redish, 2003:156-161; Trowbridge *et al*, 2000:175; Kask & Rannikmae, 2006:12; Bricker, 2005:15, McBride *et al*, 2004:434). The following skills are used and developed by using inquiry as a teaching-learning strategy:

Physical skills.

- Gathering and setting up apparatus.
- Making observations.
- Taking measurements (recording data).

Intellectual skills.

- Analysing data.
- Making comparisons.
- Evaluating results.
- Preparing reports and communicating data to other learners or the teacher.

3.3.3. The direct instruction and lecture-based models.

The direct instruction and lecture-based models are presented in a series of teaching-learning sequences that can be used in planning and designing a learning experience or when unfamiliar

knowledge is presented. These teaching strategies are characterized by short instructional periods followed by practice until mastery is attained (Gunter *et al*, 1991:2-6).

As with inquiry, these models are also a prerequisite in obtaining basic skills, probing pre-knowledge, finding facts and guiding a teaching-learning sequence (Redish, 2003:125, Gunter *et al*, 1991:65).

The following steps are observed when lecture-based and direct instruction models are used:

- Review previously learned or acquired knowledge (diagnose learners' pre-knowledge about the concept, so as to identify learners' alternative conceptions).
- State the objective for the lesson, because clearly stated objectives direct and guide learners' and teacher's goals in attainment of the objectives of the lesson.
- Present new material.
- Guide practice with corrective feedback.
- Review periodically with corrective feedback if necessary.

3.3.4 Inquiry strategy supported by direct instruction and lecture-based models.

The steps in direct instruction, lecture-based and inquiry teaching-learning models are similar, because special efforts are made to do the following (Redish, 2003:125-128, Gunter *et al*, 1991:2-8, Bybee, 2002:15):

- Probe learners' understanding.
- Engage learners in activities relevant to them.
- Challenge learners' preconceptions through concept-based questions and activities.

These strategies can consequently be integrated to facilitate the construction of scientific knowledge.

3.4 Basis for and benefits of using integrated teaching models.

According to Gunter *et al* (1991:129) and Bybee (2002:15), an integrated teaching model has the power of empirical evidence, critical analysis and careful inferences derived from

observations and experiments, which brings authority to scientific explanations. Therefore, the benefits and goals of using an integrated model appear to be many, for example (Gunter *et al*, 1991:129-131; Jonassen, 2004:135-138):

- Increase in intellectual potency.
- Conceptual thinking is learned.
- The shift from an extrinsic to an intrinsic reward is made.
- Makes learning learner-centred, thereby contributing to a person's self esteem and self-concept.
- Develops multiple, not just academic, talents.
- Discourages rote learning and memorization.
- Allows more time for learners to assimilate and accommodate information.
- Promotes positive social interactions.

3.5 Summary.

Implementation of an inquiry strategy, supported by direct instruction and lecture-based models, can be expected to guide learners to progressively develop knowledge and skills that can be used in a variety of contexts. It may also provide stimulating options for learners to solve problems creatively and to think critically when faced with new problems. These strategies are consequently in line with the outcomes, principles and requirements of OBE science, as given in the NCS (Department of Education, 2003). Therefore, they have been chosen as strategies in the intervention of the empirical study.

The next chapter deals with the research design and methodology of the empirical study. Attention is paid to aspects such as the kind of research conducted, the study population, instruments of the research design and classification and discussion of the questions used in the questionnaire.

CHAPTER 4
EMPIRICAL STUDY.
METHODOLOGY AND RESEARCH DESIGN.

4.1 Introduction.

The empirical study focuses on the accomplishment of the aim of the research as stated in paragraph 1.2, namely to investigate the effectiveness of an inquiry-based teaching-learning sequence to improve Grade 10 learners' understanding of concepts relating to the principle of conservation of mechanical energy (in a closed system). This aim is accomplished by means of action research (paragraph 4.2) in which the researcher facilitates the learning of a class of grade 10 physical science learners (paragraph 4.3). The research instrument is a questionnaire (paragraph 4.4 and 4.5) that serves both as a pre-and post-test to determine the effectiveness of the intervention (paragraph 4.6) by the calculation of the normalized learning gains (paragraph 4.7).

4.2. Research design and methodology.

4.2.1. Research methodology.

An action research methodology is used. Through action research opportunities are created where systematic reflections on classroom activities causing effective and efficient changes that are beneficial to both teaching and learning, can be made (Leedy & Ormrod, 2001:430; Feldman & Minstrel, 2000:431). As explicitly defined by Leedy and Ormrod (2001:432), action research is a way of taking a systematic, close and critical look at the way in which one teaches, with a view of changing it so that the classroom experiences become more meaningful for all those involved. Reflecting critically on what takes place in one's classroom is important to learners' learning as well as to advance the knowledge of the teaching and learning of science (Leedy & Ormrod, 2001:430; Feldman & Minstrell, 2000:431).

Action research is a contextualised form of research (it is done by the teacher on his or her own practice in his or her own classroom) and it is developmental in nature. I.e., a teacher is kept abreast and up to date with new developments in his or her discipline and profession, as is required by the Department of Education (Department of Education, 2003:5; Feldman & Minstrell, 2000:432).

The purpose of choosing action research methodology for this study is to seek ways and means of improving teaching and learning as well as to have a better comprehension of the educational environment.

4.2.2 Implementation of action research.

The research method is divided into three stages namely action planning, action taking and the evaluating stage. The method (action research) of this study allows for modification of the intended intervention after analysing, evaluating and reflecting upon the results of the pre-test. The stages of the research design are outlined as follows:

- Action planning - A pre-test questionnaire was prepared and administered to diagnose the alternative conceptions held by the learners. The alternative conceptions that have to be attended to in the intervention follows from the learners' responses.

- Action taking (intervention) - Inquiry orientated lessons were designed and presented to learners in order to remedy alternative conceptions held or to build on already existing knowledge. Six lessons of forty-five minutes each were designed. The content of the lessons is contextualised, i.e., the activities are drawn up in such a way as to engage learners to use their daily experiences and observations while responding to the situations presented. Apart from participating in the lessons, the learners carried out a research project. To do the project, the learners were divided into six groups of about six learners per group. Each group was requested to record and report instances and

situations where they had observed the application of mechanical energy transfer and its conservation from their immediate environment.

- Evaluating stage - The same questionnaire used in the pre-test was again used for the post-test. The statistical data of the pre- and post-tests is compared, analysed, interpreted and documented. Learning gains are calculated from these results. *Conclusions and recommendations follow from the results.*

4.2.3 Composition and assessment of the questionnaire/ intervention.

The introductory portion of the questionnaire consists of the biographical information and the body portion consisted of two parts namely Part 1 and Part 2 (see Appendix A). Part 3 of the questionnaire is a project. The parts of the questionnaire are discussed in the following paragraphs.

The layout of the questionnaire structure is as follows:

- ***Part 1 of the questionnaire – (diagnostic part, see paragraph 4.4).***

The pre-test and post-test results of the questionnaire (discussed in paragraph 4.4) are analysed and compared (see Tables 5.1, 5.3 and 5.5). The aim and goal of analysing and comparing these results is firstly to determine learners' alternative conceptions prior to formal instruction. Secondly, the goal and aim is to determine the occurrence of conceptual change in learners' alternative conceptions after the intervention (see paragraph 4.6) has been conducted. The conceptual change that occurred is determined by calculating the normalized learning gain as discussed in paragraph 4.7.

- ***Part 2 of the questionnaire – (conceptualised questions and item statements).***

Similar to the diagnostic part (refer to the above paragraph), the pre-test and post-test results of Part 2 of the questionnaire are also compared and analysed before and after formal instruction. The results concerning Part 2 of the questionnaire are summarized in Tables 5.2, 5.4 and 5.6.

➤ *Part 3 of the questionnaire (application stage).*

The application stage is formed by Part 3 of the questionnaire of the research study (see paragraph 4.6, lessons 5 and 6). Reports on the project results were submitted and discussions and presentations were organized. Some data from the group reports submitted and from the discussions was edited and published and presentations were made for Part 3 of the research study (see paragraph 5.4.3, Figure 1, Figure 2 and Figure 3).

4.3 Study population.

The study focuses on a group of thirty-seven grade 10-science learners (nineteen boys and eighteen girls). The learners are enrolled at Bakolobeng High School (Ganalaagte-Greater Delareyville APO) where the researcher teaches. Grade 10 learners were used to ensure that they have the scientifically correct conceptual understanding of the qualitative conceptions of energy and its conservation before it is introduced quantitatively in the FET band.

4.4 Research instrument.

A questionnaire (see appendix A) was designed and used as both a pre- and post-test. The questionnaire developed for the study is based on learners' daily experiences and observations.

The biographical information.

In the biographical portion learners are requested to fill in the following information: Their names, gender, age and the date. The names of the learners and the dates of the administration of the questionnaire are used to determine the following:

- Name: Names are used to determine the conceptual change and learning gains accomplished and whether constructive learning of individual members of the target group has taken place due to the intervention.

- Date: Dates are used to determine the maturation period of the pre-test and post-test results of the questionnaire. The maturation period for the pre-test and post-test results is one month. I.e., the same questionnaire that was used in the pre-test was administered a month after the intervention to the target group.

Part 1 of the questionnaire.

Part 1 of the questionnaire consists of six items. In each item a statement and a picture are given. The learners have to judge the correctness of the statements (called item statements). They have to choose what they think to be the most suitable response (Yes, No, Uncertain) and supply a reason to motivate their choices.

The items in this part of the questionnaire are diagnostic in nature. The aim is to find out about learners' alternative conceptions with regard to the principle of conservation of mechanical energy as discussed in paragraphs 2.3, 2.4 and 2.5.

Item statements in Part 1 of the questionnaire refer to living and non-living objects as well as relative positions and actions of objects. These objects are contrasted with one another in order to find out the nature of the learners' alternative conceptions relating to the concept of energy.

Classification of items statements in Part 1 of the questionnaire.

The items in this part of the questionnaire are compared and contrasted with one another on the basis of their similarities, positions and or the key words used. The grouping or classification is done as follows:

For items 1.1 and 1.2, similarities rely on the relative positions of the objects and the word used (*resting*). However, the difference is the surface on which the ball is resting, for example:

- Flat table (item 1.1).
- Sloping surface (item 1.2).

Items 1.2 and 1.3 of the questionnaire are grouped because in both instances the object is placed on a sloping surface. However, the contrasting words were *resting* and *speeding*.

Items 1.4 and 1.6 of the questionnaire introduce living objects. Although the objects are living they differ in their characteristics and their actions. For example:

- A cat (an animal) is sitting (item 1.4).
- A girl (human being) is stretching the strings of the bow (item 1.6).

Items 1.5 and 1.6 compare objects of similar nature and characteristics but in different situations. The catapult and the bow are used to launch stones and arrows respectively due to the elasticity of their strings. However, in the pictures they are depicted differently, for example:

- Relaxed rubber bands (item 1.5).
- Stretched bowstrings (item 1.6).

Items 1.1, 1.2, 1.3, and 1.5 all refer to non-living objects, while items 1.4 and 1.6 both refer to living objects. This grouping and classification of the item statements in Part 1 of the questionnaire is done in order to diagnose the anthropomorphic and anthropocentric views of the learners (paragraph 2.5).

Part 2 of the questionnaire.

Part 2 of the questionnaire consists of seven items with statements or questions, which require learners to respond by referring to and inferring from the pictorial scenario presented. The questions are conceptual in nature and focus on the two major kinds of energy namely kinetic and potential energy as discussed in paragraphs 2.2.3.1 and 2.2.3.2. The questions also aim to find out if learners can apply the concepts of energy and the principle of conservation of mechanical energy in everyday life situations and/or contexts as stated in paragraph 2.2.4.

Classification of questions in Part 2 of the questionnaire.

Questions 2.1, 2.2, 2.4 and 2.7 in Part 2 of the questionnaire focus on the identification of energy forms illustrated by the scenario presented. Questions 2.3, 2.5 and 2.7 addresses the concept of energy transfer taking place in the system. Lastly, questions 2.3 and 2.6 of the

questionnaire focus on the principle of conservation of mechanical energy in a system. Key words used for question 2.3 and 2.6 are *created* and *lost* respectively.

4.5 Validity and reliability of questions or item statements in the questionnaire

The reason for using the same questionnaire in both the pre- and post-tests is to determine the effectiveness of the intervention to accomplish conceptual change of the alternative conceptions revealed in the pre-test. The questionnaire should be valid and reliable. Validity of the items or questions in the survey means that the items or questions of the questionnaire should measure what is supposed to be measured. Reliability means the results should be consistent and reproducible as opposed to repeatability (Kelly & Lesh, 2000:28-29; Redish, 2003:96-97).

The content validity (the survey item should measure what it claims to measure) of the questionnaire was checked and judged by my study leader. After thorough checking and rechecking some suggestions were made to change some questions, questions statements, items, and item statements and the questionnaire was considered valid. An important factor that contributes to the validity is the composition of the items, as discussed in paragraph 4.4.

The reliability (reproducible results, not repeatable) of the questionnaire was determined by administering the same questionnaire to the target group a month later. The results of the pre- and post-tests were checked and evaluated to determine possible gains achieved (Redish, 2003:96-98). Matched items (e.g. item 1.1 and 2.4) were used to ensure reliability.

4.6 Intervention

Six teaching and learning experiences were designed in accordance with the National Curriculum Statement policy for grade 10 to 12 physical sciences (Department of Education, 2003:9-11). Attention was paid to the progression of the learners' knowledge. The teaching-learning experiences were contextualised, i.e., familiar and observable phenomena from the

learners' environment were used. Refer to appendix B for a sample of lesson plans designed for these teaching-learning experiences mentioned in paragraph 4.6.

The main teaching-learning approach used was an inquiry strategy integrated with direct instruction and lecture-based models as discussed in paragraphs 3.3.2, 3.3.3 and 3.3.4. The integrated teaching-learning approach as discussed in paragraph 3.4 is also highlighted in the learning outcomes of physical sciences in the NCS policy document (Department of Education, 2003:13-14).

Each teaching-learning experience consisted of three stages, namely:

- Stage 1: Identification of two major forms of energy.
- Stage 2: Discussion of energy changes that take place in the system and the principle of conservation of mechanical energy.
- Stage 3: Application of the energy transformation concept and the principle of conservation of mechanical energy.

The first stage (lessons 1 and 2) was designed to enable learners to distinguish energy forms (potential and kinetic energy) from types of energy (like solar, chemical, radiation, etc.) and also to identify energy forms from types in a system (e.g. heat as the average kinetic energy of particles).

The concept of energy transformation and the principle of conservation of mechanical energy were introduced in the second stage (lessons 3 and 4). The purpose of these lessons was to create conflicting situations where learners would be able to recognize their limitations in explaining the concept of energy transformation and the principle of conservation of mechanical energy and would realize that their intuitions may be opposed to the scientific explanation. Learners were also expected to be able to quote and recognize the application of the principle of conservation of mechanical energy.

The final stage (lessons 5 and 6) was designed to help learners to be able to apply and recognize the application of energy transformation and the principle of conservation of

mechanical energy in another context. In this stage learners were requested to do a case study in their environment and compile a report on situations where they had encountered or observed energy transformation and the principle of conservation of mechanical energy in application (for example, in the community a tractor with a malfunctioning self-starter is usually placed on a sloping surface in order to start). Others were asked to design (project) models where the principle could be applied (for example, some gates in the community can close automatically when opened; attaching a spring or rubber strand at one end of the gates does this).

4.6.1. Lesson plans and classroom activities.

Lesson 1 - definition of potential and kinetic energy.

In the developmental stage learners were requested to find definitions of the terms kinetic and potential energy from their textbooks. The presentation stage entailed active and interactive participation to identify energy forms in the system presented. Learners were always reminded to pay much attention to definitions given when identifying energy forms in the system. Teaching-learning materials used to facilitate the lesson were a soccer ball, a brick, and a shot put ball. During group work and reflection on the activities carried out, discussions and arguments between learners and learners and the teacher occurred freely. Teaching-learning activities designed were as follows:

Activity 1.1. Learners had to roll the balls and refer to the definitions of the terms to identify the energy form possessed by a rolling ball.

Activity 1.2. Learners had to raise and hold steady a shot put ball with an outstretched arm through different heights (knee level, waist height, shoulder height). In this activity learners had to identify the energy form possessed by the ball through these heights and then note and record the height where the ball becomes difficult to balance.

Activity 1.3. The masses of the three different objects (soccer ball, brick and shot put ball) were measured and recorded. The raising act was repeated for the three objects so that observations and comparisons could be made in order to arrive at conclusions.

Lesson 2 - a conceptualised approach.

A swing pendulum was designed as a teaching-learning aid. Learners were allowed to play with it for while. Activities that followed are outlined:

Activity 2.1. Pull and hold the pendulum at its maximum height.

Identify the energy form it possesses at this height.

Activity 2.2. Let it return to its equilibrium position and hold it stationary at this position (minimum height).

Identify the energy form the pendulum has at this position.

Compare the two positions of the pendulum and indicate at which position it has more energy while at rest.

Activity 2.3. Let the pendulum swing.

Identify and note the energy forms that are displayed during its swings.

Activity 2.4. From your knowledge and experience name any mechanism or apparatus from your environment that has similar features to this pendulum.

Lesson 3 and 4 - the principle of conservation of energy.

In lessons 3 and 4 the principle of conservation of energy was introduced. In the introductory phase learners were provided with dictionaries to look up the words “law” and “conservation” and instructed to write down their meanings. The purpose was to make learners aware of the meanings of these words in everyday language use as opposed to their meaning in science. Activities, which followed to help learners, are reflected in the layout and design of lesson plans (see appendix B).

The lesson plans were designed according to NCS grade 10 to 12 physical sciences lesson planning requirements and standards (Department of Education, 2003:17). A sample of one of the lesson plans designed is included in Appendix B.

Lessons 5 and 6 - application stage.

A contextual project performed by groups of learners formed the application stage. In this stage learners were requested to conduct a case study from their immediate environment. In the case study the learners were requested to identify and recognize the application of the concept of energy and the principle of conservation of mechanical energy from their immediate environment.

As discussed in paragraph 5.4.3, supporting evidence from their environment of learners' comprehension of the application of the concept of mechanical energy and its conservation was depicted by pictorial information brought forward as well as presentations, reports and discussions that followed (see Figures 1, 2 and 3).

4.7 Processing of the results.

According to Hake (2000:1-10), Meltzer (2002) and Redish (2003:43), consistent analysis of pre-test and post-test results of a survey over a diverse student population in high schools, colleges, and universities is obtained and worked out as an average normalized gain. The average normalized gain is calculated as follows:

Average normalized gain = Actual learning gain ÷ Maximum possible gain.

The actual learning gain for the survey items in the questionnaire is obtained by working out the difference between the pre-test percentages the post-test percentages. It is calculated as follows:

Actual learning gain = post-test % - pre-test%.

The maximum possible gain is obtained by subtracting the pre-test percentage from a hundred percent. It is calculated as follows:

Maximum possible gain = 100% - pre-test %.

4.8 Summary.

The empirical study focused on the three *W and H* questions. I.e., *what* was being researched (paragraph 4.1), *why* and *how* the study was conducted (paragraphs 4.2, 4.4, 4.5 and 4.6). The *who* question was addressed by the study population and the researcher as discussed in paragraph 4.3. In the next chapter, learners' general problems regarding the principle of conservation of mechanical energy are identified. Data is collected and recorded (paragraph 5.4) while the pre- and post-test results (tables 5.1, 5.2, 5.3 and 5.4) are analysed and discussed. The calculations of the normalized learning gains as discussed in paragraph 4.7 and shown in tables 5.5 and 5.6 are also discussed.

CHAPTER 5

RESULTS AND ANALYSIS.

5.1 Introduction.

The analysis of the results of the empirical study is done according to the aims, design and layout of the parts in the questionnaire of the survey study as discussed in paragraph 4.2.3. The purpose is to determine to what extent learning gains were achieved through conceptual change of alternative conceptions. Comparing the results of the pre- and post-test questionnaire does this.

This chapter presents data of classroom observations and learners' common responses to questions during the intervention (paragraph 5.4), comparisons and analyses of learners' responses to questionnaire items (paragraphs 5.2, 5.4 and 5.5) and a statistical analysis of the pre- and post-test results and the learning gains achieved after the intervention (paragraph 5.6).

5.2 Results of questionnaires: Biographical information.

The results of the biographical information requested from the learners as mentioned in paragraph 4.4.1 are as follows:

- Age: From their respective ages, an average age was calculated to determine the learners' level of cognitive development and compare it to the appropriate admission age for grade 10 as dictated by South African School Act's admission policy requirement (SASA, 1996:B-62). The average was found to be sixteen years for the target group (grade + 6 years of age) and this complied with the policy as stated.
- Gender: Gender was used to determine the composition of the class, i.e. how many girls and how many boys the class was composed of. The ratio of boys to girls was calculated and found to be approximately equal (19 boys and 18 girls). The ratio was 1:1.

5.3. Analysis of pre-test results.

5.3.1. Part 1 of the questionnaire (diagnostic questions).

Table 5.1 summarizes the pre-test results of Part 1 of the questionnaire. Learners' responses to the questionnaire items gave an indication of alternative conceptions held, as discussed in paragraph 5.3.2.

Table 5.1. Learners' responses to the diagnostic questions or item statements.

ITEMS	TOTAL	RESPONSES (out of 37)			% OF CORRECT RESPONSES
		YES	NO	UNCERTAIN	
1.1	37	21	13	3	56
1.2	37	17	16	4	46
1.3	37	28	6	3	77
1.4	37	26	6	5	70
1.5	37	14	18	5	37
1.6	37	31	6	0	83

The learners performed best in items 1.3, 1.4 and 1.6, while percentages below 50 % were obtained in items 1.2 and 1.5. Both the latter items referred to non-living objects at rest. In order to interpret these results, the reasons that learners gave for their answers were analysed (paragraph 5.3.2).

5.3.2. Part 1 of questionnaire: Reasons.

The variety of reasons that the learners gave for their answers was so large that it is not possible to discuss them all. Therefore, five learners were sampled randomly to give an indication of their reasoning. In the paragraphs below the responses of the sampled learners for Part 1 of the questionnaire are presented, compared and discussed as follows:

- Step 1- learners' responses are presented for each item.
- Step 2- learners' responses are categorized, compared and discussed.

Learners' responses were analysed, classified and categorized according to the nature and origin of the alternative conception held.

The five randomly sampled learners gave the following reasons for their responses to the items:

Item 1.1. (A ball resting on a flat surface).

John: *"No, because the ball has lots of air inside. So it has no energy."*

Otshepeng: *"Yes, if the table is taken out the ball is going to fall down."*

Lilian: *"Yes, because is big ball on top of the table."*

Lephahamiso: *"Yes, because it has energy to rest on top of the table."*

Alinah: *"No, if the ball rolls down it has energy and if it is standing or resting it has no energy."*

These responses were categorized and analysed as follows:

Association of energy with size: Lilian and John associated energy with size. Lilian responded by indicating that since the ball is big it has energy and John said a light ball has no energy.

Association of energy with motion: Otshepeng and Alinah referred to conditions that might cause the motion of the ball (it is going to "fall down" and it "rolls down"). This is a notion that can be used to improve the learners' understanding of the science concept of potential energy relative to a reference plane.

Everyday language use: Lephahamiso (it has energy to rest) and Alinah (if it is resting or standing it has no energy). This might mean that objects at rest have reserve energy or objects at rest are exhausted.

Item 1.2. (A ball resting on a sloping surface).

John: *"Yes, the slope is not like table. So the ball will want to move on top of the table."*

Otshepeng: *“No, the ball want to go down now it is resting.”*

Lilian: *“No, it does not go down, it does not energy to go down.”*

Lephahamiso: *“No, because it has to move when it is on the slope and that ball is not moving.”*

Alinah: *“Yes, because it is using energy to stop rolling down.”*

Association of energy with motion: John (“will want to move”) and Otshepeng (“wants to go down”). These learners reasoned that given the nature of the slope, the ball will eventually roll down and when it is rolling, it is moving and it possesses energy.

Everyday language use: Lilian (“it does not go down”), Lephahamiso (“is not moving”) and Alinah (“it is using energy to stop rolling down”). These arguments might mean that if the ball had energy, it would have moved because there is a slope. This might be associated with a person feeling tired and saying he does not have energy to move.

Item 1.3. (A rolling ball on a sloping surface).

John: *“Yes, a ball is moving and it has moved by a slope, it has energy.”*

Otshepeng: *“Yes, because it falls down, it has energy.”*

Lilian: *“Yes, when it goes down it gains energy because it is rolling and it has motion.”*

Lephahamiso: *“Yes, because when the ball moves it gain energy than when it is not.”*

Alinah: *“Yes, because it moving down, and it using energy to roll down.”*

Association of energy with motion: All learners were consistent in responding to this item. Since the ball was rolling, reference to motion was illustrated by the following key words picked from learners’ responses to this item:

John: *“moving.”*

Otshepeng: *“falls down.”*

Lilian: *“rolling and it has motion.”*

Lephahamiso: *“the ball moves.”*

Alinah: *“moving down.”*

Item 1.4. (A sitting cat).

John: *“Yes, because if someone scars it, it will run away immediately. I think when it is sitting it has lot of energy.”*

Otshepeng: *“Yes, because this cat has energy. If there is no energy the cat will not live.”*

Lilian: *“No, I think this cat is too hungry, it seems that this cat does not have energy.”*

Lephahamiso: *“Uncertain, because I am not sure whether the cat have energy or does not have energy.”*

Alinah: *“Yes, because you can see it look like it will jump something or do something. is looking like it can kill something.”*

Association of energy with living objects: John (if scared, it will run away because at that position it has energy), Otshepeng (“If there is no energy the cat will not live.”) and Alinah (“it looks like it will jump”). These answers imply that the cat is a living being and it has energy whether it is at rest or not. The association of energy with living beings or with what they do is anthropomorphic in nature.

Association of energy with motion and from everyday language use: Lilian (“I think the cat is hungry”). This might mean that when a person says she/he is hungry, he or she does not have energy to do anything. Alinah (“it looks like it will jump”). The word *jump* indicates movement and more emphasis is put on the activity of the cat.

Lephahamiso was uncertain and her uncertainty could be attributed to the sitting position of the cat. I.e., she knows or might understand that the cat is living and has energy, but because of its sitting position, the cat was tired and hence it does not have energy.

Item.1.6. (The girl with bow strings stretched).

John: *“Yes, the girl is giving the strings energy.”*

Otshepeng: *“Yes, because this girl help stretched to get energy.”*

Lilian: *“Yes, it is having because of the girl. The girl gives it energy by pulling it.”*

Lephahamiso: *“Yes, the girl is pulling the strings to give them energy.”*

Alinah: *“Yes, it having energy of the girl.”*

Energy as a human centred activity: The catapult is isolated from the system as illustrated by the learners’ responses. Energy is only considered as human activity. This is illustrated by the responses of the learners for item 1.6.

These sampled responses that were correct for items 1.4, 1.3 and 1.6 show that many learners associated energy with living beings and motion. As reflected from their responses, the strings of the bow in item 1.6, even if they were held stretched, were not considered to possess energy. The anthropomorphic and anthropocentric views of energy are revealed by these responses (see paragraph 5.3.3).

Item 1.5 was poorly responded to as compared to the other items already analysed and discussed (37% of the responses recorded was correct, see table 5.1). The poor responses for this question can be attributed to the anthropomorphic and anthropocentric views of the learners. These views are also revealed from the reasons given by learners when responding to the statement of this item.

Item 1.5. (Relaxed rubber bands of the catapult).

John: *“Yes, because it has energy to push the stone to hit someone or something, but if there is no one pulling it, there will be no energy.”*

Otshepeng: *“No, because they have no energy.”*

Lilian: *“No, because these rubber bands are resting.”*

Lephahamiso: *“Yes, because those rubber bands give the stone energy.”*

Alinah: *“No, because there is no one pulling the catapult.”*

The human centred energy view is also displayed in this item (it has similar features to item 1.6). The following ideas were picked up from learners’ responses:

John: *“if there is no one pulling it, there will be no energy.”*

Alinah: *“there is no one pulling the catapult.”*

For Otshepeng (“they have no energy”) and Lilian (“are resting”) the responses indicated that since the rubber bands are not stretched, the rubber bands are at rest and therefore they do not possess energy. Or, because there is no human element in the system, the rubber bands on their own cannot possess energy.

Lephahamiso (“give the stone energy”) was the only one to indicate that the rubber bands have energy because they can launch stones. A limited and unclear comprehension of the concept of potential energy was displayed by Lephahamiso’s response.

John and Alinah’s responses (“there is no pulling”) imply an understanding that work has to be done to give the catapult energy. None of the learners considered energy that objects possess on the microscopic level due to vibration or motion of atomic or molecular particles, or forces between the particles.

These results also confirm the findings of Driver and Warrington (1985:171), Boyes and Stanisstreet (1990:51), Kabapinar *et al*, (2004:636), Wesi, (2003:248), Osborne and Freyberg (1995:6-7) and Watt (1995:214-216) as discussed in paragraphs 2.3, 2.4 and 2.5.

Summary.

In synthesizing the results for part 1 of the pre-test the following factors were identified:

- Language proficiency of the learners was lacking and inadequate. This is highlighted in paragraph 1.4.
- Learners’ pre-knowledge about the concept of energy and energy forms in the system was confused and blurred. This is illustrated by their inconsistent responses to questionnaire items.
- Learners’ alternative conceptions of energy tend to be anthropocentric and anthropomorphic in nature.
- Kinetic energy is better understood than potential energy.

- Although limited, learners display ideas about energy that can be linked onto, broadened and refined in order to learn the scientific conception of energy, as is proposed by the constructivist theory (paragraph 3.3.1).

5.3.3. Part 2 of the questionnaire (Conceptualised questions or item statements).

For Part 2 of the questionnaire, which was designed to test conceptual thinking and reasoning, learners still maintained a tendency of associating energy with living beings and objects in motion. This can be deduced from the results of questions 2.1, 2.2, 2.4 and 2.7 of the questionnaire (see table 5.2). Responses for question 2.3, 2.6 and 2.7 show that the majority of the learners did not yet comprehend the principle of conservation of energy and energy transfers depicted. For question 2.5 the responses were exceptionally good because the concept of force and work were dealt with before. The following responses of the learners were noted, analysed, evaluated and discussed. The pre-test results for Part 2 in the questionnaire of the survey study are communicated in the following table (table 5.2).

Table 5.2. Learners' responses to the conceptualised questions or item statements.

Questions	Total	RESPONSES (out of 37)			% of Correct responses
		Yes	No	No response	
2.1	37	15	22	0	41
2.2	37	33	4	0	89
2.3	37	22	15	0	41
2.4	37	9	27	1	24
2.5	37	35	0	2	95
2.6	37	27	10	0	27
2.7	37	17	18	2	46

Apart from items 2.2 and 2.5, the learners did not perform well. The reason for this is discussed in the next paragraph (5.3.4).

5.3.4. Part 2 of the questionnaire: Reasons.

The same procedure for comparing and discussing the responses of the sampled learners to Part 2 of the questionnaire was followed as presented in paragraph 5.3.2 for Part 1 of the questionnaire.

Item 2.1. (The stone inside the catapult).

John: *“No, the stone is rested inside the catapult.”*

Otshepeng: *“No, the boy has energy, not the stone.”*

Lilian: *“No, the stone is at rest.”*

Lephahamiso: *“No, because the stone doesn’t that shows that it only gain energy when it is moving.”*

Alinah: *“No, the boy is holding the stone inside the catapult. So it is not having energy.”*

John, Lilian, Lephahamiso and Alinah depicted association of energy with motion. The following ideas were picked up from their responses:

John: *“stone is rested.”*

Lilian: *“stone is at rest.”*

Lephahamiso: *“it only gains energy when it is moving.”*

Alinah: *“the boy is holding the stone inside the catapult.”*

The implications of the given responses show that learners think that when the object is at rest, it does not possess energy (John, Lilian, Alinah and Lephahamiso).

Item 2.2. (The launched stone).

John: *“Yes, it has energy because it goes straight to the tin.”*

Otshepeng: *“Yes, the stone is flying.”*

Lilian: *“Yes, the stone is in the air and it is moving.”*

Lephahamiso; *“Yes, because if the stone didn’t have energy it would have fallen down while it was fired.”*

Alinah: *“Yes, the stone will hit the tin with more energy.”*

Association of energy with motion was further displayed by the following key words from learners' responses to item 2.2:

John: "*it goes straight to the tin.*"

Otshepeng: "*the stone is flying*"

Lilian: "*the stone is in the air.*"

Lephahamiso: "*if the stone didn't have energy it would have fallen down.*"

Alinah: "*the stone will hit the tin.*"

Item 2.4. (The tin on top of the drum).

John: "*No*" (no reason supplied).

Otshepeng: "*No, it is not moving.*"

Lilian: "*No, I think when the tin is standing on top of the drum it has no energy until the stone hits it.*"

Lephahamiso: "*No, it does not have because it is standing.*"

Alinah: "*No, it must be hit first.*"

All learners responded by saying no and the reasons supplied by four learners (all except John) emphasized the association of energy with motion. The conception of gravitational potential energy due to the object's position above a reference level is not revealed in their responses.

Item 2.5. The concept of work.

Item 2.5 was well responded to because the concept of force and work had been previously dealt with. The following learners' responses for item 2.5 were picked up and recorded:

John: "*Yes, the stone hit the tin and move it.*"

Otshepeng: "*Yes, because when the stone hit the tin it moved.*"

Lilian: "*Yes, when the tin falls, it shows force moves it.*"

Lephahamiso: "*Yes, it was doing work on falling tin.*"

Alinah: "*Yes, the tin moves and falls down.*"

Item 2.7. (The falling target).

John: *“Yes, because it fall down and now it does have energy.”*

Otshepeng: *“Yes, the energy is there because both the tin and the stone use energy to fall down.”*

Lilian: *“Yes, the tin will fall down with the energy of the stone.”*

Lephahamiso: *“Yes, because it is falling.”*

Alinah: *“Yes”* (no reason supplied).

The falling tin has energy because the word falling illustrates motion. This further indicates the association of the concept of energy with motion.

Association of energy with motion is depicted by responses for items 2.1, 2.2, 2.4 and 2.7 (John, Lilian, Alinah and Lephahamiso).

Item 2.3. (Energy changes and the principle of conservation of energy).

John: *“Yes, the catapult created energy for the stone.”*

Otshepeng: *“Yes, because the catapult has the string and that string gives and created energy for the stone.”*

Lilian: *“Yes, because the catapult makes the stone moves.”*

Lephahamiso: *“Yes, if there was no catapult, energy could not be created for the stone.”*

Alinah: *“Yes, I think a person who pulls the catapult, because he/she uses lot and lot of strength, creates energy.”*

Item 2.6. Energy changes and the principle of conservation of energy.

John: *“Yes, because the stone is falling and is going to rest.”*

Otshepeng: *“Yes, the stone loses energy.”*

Lilian: *“I don’t know.”*

Lephahamiso: *“Yes, the stone will be rested and the tin will fall.”*

Alinah: *“Yes, because the stone will fall down and rest.”*

The concept of energy conservation and energy changes taking place in a system is not known as illustrated by the learners' answers for items 2.3 and 2.6. Key words used for the items were "*created*" and "*lost*". Learners responded wrongly by saying energy was *created* by the catapult and was *lost* by the stone after hitting the tin.

Summary.

The results for Part 2 of the questionnaire confirm the anthropomorphic and anthropocentric views held by learners with regard to the concept of energy as reported by Watt (1985:214-216) and Wesi (2003:260) (see paragraph 2.5). Learners also strongly associate energy with motion.

Tables 5.1 and 5.2 summarize the pre-test results by which one can arrive at assumptions and conclusions about the nature of learners' alternative conceptions regarding the concept of energy and the principle of conservation of mechanical energy. Secondly, these results also provide some ideas for the teacher to design his or her teaching and learning activities in a constructivist manner in order to enhance meaningful and effective teaching and learning of the concepts.

5.4. Classroom observations during the intervention.

While doing the inquiry activities of the intervention (paragraph 4.6), the learners responded to oral questions asked by the teacher as well as written questions on prepared work sheets.

5.4.1 Results for lesson 1.

From the activities carried out during the teaching-learning sequences designed to remedy learners' alternative conceptions about the concept of energy and the law of conservation of energy, as discussed in paragraph 4.6.1, the following were common responses from learners to guiding questions asked by the teacher:

Activity 1.1. Two balls (shot put and soccer ball) are rolled along a flat horizontal surface.

Guiding questions:

- Do the rolling balls possess energy?
- From the list of scientific definitions of terms, identify the energy form possessed by the rolling balls.

Common responses:

- The balls have energy because they are moving.
- The balls have energy of motion.
- The balls have kinetic energy.

Activity 1.2. The raising act. Learners had to raise and hold steady a shot put ball at different levels (e.g. knee level, hip level and shoulder height).

Guiding questions:

- What energy form does the ball possess through these heights?
- At which height do you find it difficult to balance the shot put ball?
- Compare the height through which the ball was raised to the work done to raise it and draw conclusions from your observations.

Common responses:

- The ball possesses stored energy.
- The energy is due to position.
- Potential energy is seen as stored energy.
- It is easy to lift the ball to knee level.
- At shoulder height the ball seems to be heavier.
- At shoulder height the ball is more difficult to balance as compared to knee level.
- There is more potential energy at shoulder height.
- The higher you raise the ball the more work is done.

Activity 1.3. The raising act as in activity 1.2 was repeated using two balls (soccer and shot put).

Guiding questions:

- Which ball is the lighter of the two?
- Which ball is easy to raise through the different heights mentioned? Motivate your answer.
- Which ball will hurt you most if it fell on your toe? Motivate.

Common responses:

- The soccer ball is lighter than the other materials.
- The soccer ball is easy to be raised through different heights because it is the lightest.
- The shot put ball is difficult to be raised because it is heavier than the other materials.
- The shot put ball will hurt most if it falls on your toe.
- The shot put ball will break your toe because it has *more mass*.
- The shot put ball has more *stored energy* and it will break your toe.

Analysis of the responses:

Analysis of the responses for activity 1.1 gives an indication that energy due to motion is always recognized. A reason could be that energy is associated with motion in everyday life (paragraph 2.5) as well as in science (paragraph 2.2.3).

For activity 1.2 the concept of the gain in potential energy was gradually developed because learners were able to recognize that the ball was difficult to be raised to shoulder height as compared to knee level. For activity 1.3 learners were able to tell that an object with more mass possesses more stored energy. It is interesting to note the responses that refer to the consequences of having a high potential energy (e.g. “break your toe” and “hurt most”). This idea corresponds with the scientific concept of energy as the ability to do work. A conceptual understanding of the concept of work and the dependence of potential energy to the height and mass of an object, paves the way to formalization of the concepts.

5.4.2 Results for lesson 2.

The following responses were recorded during the activities:

Activity 2.1. The swinging pendulum.

Guiding questions:

- The pendulum is at rest or equilibrium. What energy form does it possess?
- The pendulum is pulled and held stationary at its maximum position. What energy form does it possess at this position?

Common responses:

- If it is not moving it has potential energy.
- It is high up there, therefore it has potential energy.

Activity 2.2. The swinging pendulum continued.

Guiding questions:

- Measure and compare the heights at which the pendulum is held stationary (at equilibrium and when pulled to its maximum position).
- Identify the energy form possessed by the pendulum at these heights.
- At which height does the pendulum possess more energy?

Common responses:

- It is held at rest so it has stored energy.
- If it is not moving it has energy.
- At the highest position there is more stored energy.
- There is more energy at the top.

Activity 2.3. The swinging pendulum (energy changes within the system).

Guiding questions:

- The pendulum is allowed to swing. Identify the energy forms displayed by the swinging pendulum.

Common responses:

- When it is high up there it has potential energy.
- However, when it swings it has energy of motion.
- Swinging is shaking and moving so it possesses kinetic energy.
- When it starts to swing, potential energy is converted to energy of motion.

Analysis of the responses:

The concept of energy changes (when the pendulum swings - energy of motion) taking place in a system was gradually introduced and learners were able to recognize that energy is the property of objects (living and non-living). This was evident from their responses that the object possessed stored or potential energy “when high up there”.

The application of the concept of energy change was also readily observed from their immediate environment (see activity 3) because the constructed swinging pendulum operated similarly to the children’s swings on the village playground. While some learners correctly associated the gravitational potential energy of an object with its relative position to the earth, others only associated it with being at rest (or not moving). The idea that only and all stationary objects have potential energy is an alternative conception (paragraph 2.5).

5.4.3 Contextualised project (Activity 3).**Guiding activities and questions:**

- From your immediate environment, observation and experience mention and name anything that operates in a similar fashion to the swinging pendulum.
- Construct a model of this mechanism.

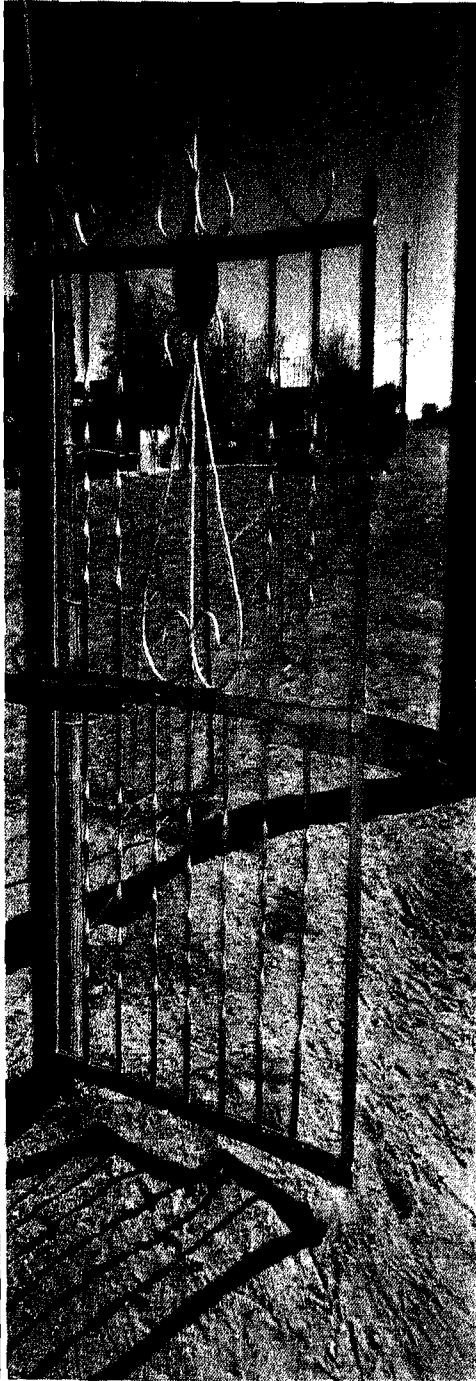
Common responses:

- The children’s swings on the village playground were readily and quickly mentioned.
- Models of children’s swings were constructed.

The following figures illustrate the reports submitted and the outcomes of the research study conducted by learners from their immediate environment regarding the concept of energy and the principle of conservation of mechanical energy. The presented pictures, discussions and reports that followed from this research study conducted by learners, show that learners were able to recognize and appreciate the application of the concept of energy and the principle of conservation of mechanical energy from their environment.



FIGURE 1: A tractor with a defective or malfunctioning battery or self-starter is always put on a sloping plane



OPEN



CLOSED

FIGURE 2: An automatic gate (a spring is attached to a gate for it to close on its own)



Sliding ramp.



Swings.

FIGURE 3: The village playground (children's swings and sliding ramp).

Interactive discussions through questioning as well as detailed evaluations of the reports and pictures presented were held with learners about the case study conducted by them. The following scientifically correct information from the learners was recorded:

FIGURE 1.

- The tractor at the top of the incline possesses more potential energy than at the bottom of the incline.
- When the tractor is allowed to roll down the incline, it gains kinetic energy (potential energy is transferred to kinetic energy as it moves down).
- Half way down the incline the tractor possesses an equal amount of kinetic energy and potential energy.
- At the end of the incline, kinetic energy is more than potential energy.

FIGURE 2.

A brief interactive discussion on the mechanism of the operation of the gate was given as follows:

Mechanism.

Parts and the method of construction of the gate were indicated and named by referring to the picture, i.e., a picture of the gate was displayed to the audience (refer to figure 2).

Operational details.

A model gate was presented and the operational principles explained as follows:

- When opening the gate the spring stretches, thus the kinetic energy of the gate is transferred to the stretching spring (the stretching spring gains potential energy by doing work).
- When releasing the gate, the potential energy of the spring is transferred to the gate. The gate then moves, closes down or returns to its original position.

FIGURE 3.

The swings and sliding ramps are familiar and common on the playgrounds of the village. Learners had vivid experiences of the swings and sliding ramps. The following experiences were relived in conjunction with the energy changes that took place during the swinging and sliding:

- At the top of the sliding ramp potential energy is high and at the bottom of the sliding ramp kinetic energy is high.
- At the highest point of the swing potential energy is high and at the lowest point kinetic energy is high.
- During the downward motions, potential energy is converted to kinetic energy.
- Energy is conserved.

In this regard it is evident that learners were able to identify the energy forms in the system, to recognize energy changes that took place in the system and name instances where the application of the principle of conservation of energy in mechanics was evident. The report of the learners on these contextualised situations reveals a progress in their attainment of the scientific conceptions of kinetic and potential energy, change in energy forms as well as the principle of conservation of mechanical energy.

5.5. Post-test results.

5.5.1. Post-test Part 1 (diagnostic questions or item statements).

The outcomes of the post-test results are outlined in tables 5.3 and 5.4. These results serve as a yardstick to diagnose and determine whether scientifically correct conceptions were constructed after the intervention phase as discussed in paragraph 4.2.3. The responses of the same sampled learners for the post-test results of Part 1 and Part 2 of the questionnaire show that learners were able to recognize, identify and name energy forms in the system. The concept of energy as a property of both living and non-living matter was also established.

Table 5.3 provides the results of the post-test for Part 1 of the questionnaire after the intervention was conducted.

Table 5.3 Learners' responses to the diagnostic questions or item statements.

Item	Total	RESPONSES (out of 37)			% Of Correct responses
		Yes	No	Uncertain	
1.1	37	34	2	1	91
1.2	37	34	3	0	91
1.3	37	33	2	0	89
1.4	37	34	3	0	91
1.5	37	30	6	1	81
1.6	37	36	0	1	97

After the intervention was conducted (as discussed in paragraph 4.6.1, activities 1.1, 1.2 and 1.3), a high percentage of above 80 for all items (1.1 to 1.6) of Part 1 of the questionnaire was obtained as reflected in table 5.3. This indicates that learners were able to note and observe that energy is the property of all matter (whether living or non-living). Learners were also able to differentiate and name energy forms in the system. To illustrate this the post-test responses of the same sampled learners for items 1.1 to 1.6 are given. These responses were analysed in the same way as in the pre-test for Part 1 of the questionnaire (refer to paragraph 5.3).

Responses for part 1 (items 1.1 to 1.6) show that consistency existed when learners responded to questionnaire items after the intervention was conducted. Key words like “energy of motion”, “stored energy”, “potential” and “kinetic energy” were used correctly by most learners.

The learners readily accepted the idea of potential energy as stored energy. This is an intermediate term for the concept on the path to a more scientific conception (Kaper & Goedhart, 2002; Duit, 1981) as discussed in paragraph 2.2.3.2.

5.5.2. Post-test Part 2 (conceptualised questions or item statements)

The post-test results for Part 2 in the questionnaire of the survey study done after the intervention was conducted are represented below in table 5.4.

Table 5.4 Learners' responses to the conceptualised questions or item statements.

Question	Total	RESPONSES (out of 37)			% Of Correct responses
		Yes	No	No response	
2.1	37	36	1	0	97
2.2	37	35	2	0	94
2.3	37	23	14	0	62
2.4	37	31	6	0	83
2.5	37	36	1	0	97
2.6	37	10	27	0	73
2.7	37	35	2	0	94

Learners' responses to the post-test were also analysed as for the pre-test (paragraph 5.3).

For items 2.1 and 2.2 energy forms in the system were recognized, named and mentioned, for example:

Item 2.1: stored energy.

Potential energy.

Item 2.2: energy of motion

Kinetic energy.

Learners also accepted that non-living objects could have energy, even while stationary.

In items 2.3, 2.4, 2.6 and 2.7 energy changes taking place in a system were referred to. For example, learners were able to identify that before the tin was hit it had potential energy, but when falling it was converted to kinetic energy. This indicates that the realization of energy changes taking place in a system were observed and noted.

The post-test results of Part 2 (table 5.4) in the questionnaire show significant improvement of the learners' conceptions about the concept of energy, energy conversions and the principle of conservation of mechanical energy. This follows from the learners' ability to identify and name kinds of energy in the system as well as their ability to notice and recognize energy transformation taking place within the system.

The conceptual change that occurred due to the intervention is shown by learners' responses to questions and item statements in the questionnaire. The learners' usage of scientific words like potential and kinetic energy when responding to questions depicted this. In order to measure the effectiveness of the intervention in accomplishing conceptual change, the results were analysed statistically (paragraph 5.6).

5.6 Statistical analysis of the results

Tables 5.5 and 5.6 present the statistical analysis of the results by comparing pre- and post-test results of both Part 1 and Part 2 of the questionnaire through calculation of the average normalized learning gain (paragraph 4.7). The average learning gain achieved for each question or item statement was worked out using the following formula:

Gain = actual average gain ÷ maximum possible gain (Redish, 2003:43). (Refer to paragraph 4.7 in chapter 4).

To illustrate the calculations, the normalized gain for item 1.1 of the questionnaire (table 5.1) was determined as follows:

$$\begin{aligned}\text{Actual average gain} &= \text{post-test \%} - \text{pre-test \%} \\ &= 91\% - 56\% = 35\%.\end{aligned}$$

$$\begin{aligned}\text{Maximum possible gain} &= 100\% - \text{pre-test \%} \\ &= 100\% - 56\% = 44\%.\end{aligned}$$

The average normalized gain = actual average gain ÷ maximum possible gain

$$35\% \div 44\% = 0.8.$$

Expressed as percentage, the normalized gain is 80 % for item 1.1 of the questionnaire. This means that, learners had a learning gain of 0.8 or 80%.

5.6.1. Part 1 of the questionnaire

Table 5.5 shows the calculated average normalized gains for each question or item statement as well as the total average normalized gain for Part 1 of the questionnaire.

Table 5.5 Calculated normalized gain for Part 1 of the questionnaire.

ITEM	ACTUAL GAIN POST – PRE-TEST%	POSSIBLE GAIN 100% - PRE-TEST%	NORMALIZED GAIN $\frac{\text{ACTUAL GAIN \%}}{\text{POSSIBLE GAIN\%}}$	EXPRESSED AS % NORMALIZED GAIN * 100 %
1.1	91% - 56% = 35%	100% - 56% = 44%	35% ÷ 44% = 0.8	80
1.2	91% - 46% = 45%	100% - 46% = 54%	45% ÷ 54% = 0.83	83
1.3	89% - 77% = 12%	100% - 77% = 23%	12% ÷ 23% = 0.52	52
1.4	91% - 70% = 21%	100% - 70% = 30%	21% ÷ 30% = 0.7	70
1.5	81% - 37% = 44%	100% - 37% = 63%	44% ÷ 63% = 0.7	70
1.6	97% - 83% = 14%	100% - 83% = 17%	14% ÷ 17% = 0.82	82
TOTAL AVERAGE			4.37 ÷ 6 = 0.72	72%

The total average normalized gain gives the summary or the average normalized gain for Part 1 of the questionnaire. The last column of the table gives the gains expressed in percentage form. The total average normalized gain for Part 1 is 72%.

The normalized gain for item 1.3 of Part 1 of the questionnaire is significantly lower than the normalized gains of the other items (item 1.1, 1.2, 1.4, 1.5 and 1.6). It can be deduced from the results of the pre- and post-test in table 5.1 that the learners performed well for this item. The reason might be that during the pre-test learners overemphasized the word *speeding* and

associated it with energy possessed by a rolling ball (see paragraph 5.3). In the post-test (paragraph 5.4), learners were able to indicate the kind of energy illustrated by the rolling ball.

5.6.2. Part 2 of the questionnaire.

The normalized gains for each item statement or question and the total average normalized gains of Part 2 of the questionnaire are calculated and determined in a similar manner as that of Part 1 of the questionnaire. The calculations mentioned are outlined in table 5.6 for Part 2 of the questionnaire.

Table 5.6 Calculated normalized gain for Part 2 of the questionnaire.

ITEM	ACTUAL GAINS	POSSIBLE GAIN	NORMALIZED GAIN	NORMALIZED GAIN EXPRESSED AS %
	POST- PRE-TEST%	100% - PRE-TSET%	$\frac{\text{ACTUAL GAIN\%}}{\text{POSSIBLE GAIN \%}}$	
2.1	91% - 41% = 50%	100% - 41% = 59%	$50\% \div 59\% = \mathbf{0.84}$	84
2.2	94% - 89% = 5%	100% - 89% = 11%	$5\% \div 11\% = \mathbf{0.5}$	50
2.3	70% - 41% = 29%	100% - 41% = 59%	$29\% \div 59\% = \mathbf{0.5}$	50
2.4	83% - 24% = 59%	100% - 24% = 76%	$59\% \div 76\% = \mathbf{0.78}$	78
2.5	97% - 95% = 2%	100% - 95% = 5%	$2\% \div 5\% = \mathbf{0.4}$	40
2.6	73% - 27% = 46%	100% - 27% = 73%	$46\% \div 73\% = \mathbf{0.63}$	63
2.7	94% - 46% = 48%	100% - 46% = 54%	$48\% \div 54\% = \mathbf{0.89}$	89
TOTAL AVERAGE			$\mathbf{4.54 \div 7 = 0.64}$	64

The total average normalized gain for Part 2 of the questionnaire is 0.64 and expressed as a percentage the normalized gain for Part 2 of the questionnaire is 64%.

In order to determine the total normalized gain, the two averages were added (average normalize gain of Part 1 + average normalized gain of Part 2 of the questionnaire) and divided by two. This was calculated as follows:

Grand total (average normalized gain) is thus = $\frac{0.72 + 0.64}{2}$

2

$$= 0.68.$$

Expressed as a percentage the learners achieved a learning gain of 68%. The high value of the average normalized gain (0.68) indicates that there was constructive conceptual change on the part of the learners regarding the concept of energy and the principle of conservation of mechanical energy (Hake, 2002:3). This normalized gain provides an indication of the effectiveness of the contemporary teaching-learning approaches as well as the use of context infused content used in the empirical study.

5.7. Summary.

Analysis of the learners' responses for the activities designed and implemented during the intervention shows that learners were able to recognize and name different forms of energy (either kinetic, potential or both forms of energy). It also shows progress in the learners' understanding that potential energy can gradually be transferred to kinetic energy (and vice versa), while the total amount of mechanical energy remains constant in a closed system. Their application of the energy concept and the principle of conservation of energy from their immediate environment were observed in the project as discussed in paragraph 5.4.

Learners' conceptual change was accomplished by the intervention. The anthropomorphic and anthropocentric views of learners regarding the concept of energy were gradually replaced by a more scientific meaning of the concepts (see paragraph 5.5). Learners' association of gravitational potential energy with all and only with stationary objects was changed to an understanding of the concept in terms of work done and the relative position above a reference level. The knowledge construction and conceptual changes that occurred during and after the intervention process is further confirmed by the statistical analysis of the pre-test and post-test results of the questionnaire as discussed in paragraphs 5.4, 5.5, and 5.6. The large value of the average normalized learning gain (68 %) shows the effectiveness of the intervention in accomplishing conceptual change. The learners made good progress on their way towards an understanding of the scientific concepts relating to the principle of conservation of mechanical energy, although there is much room for further improvement. The scope, findings,

recommendations, suggestions for further areas of research and concluding remarks are discussed in the next chapter.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSIONS.

6.1 Introduction.

The focus of this chapter is to present the scope, findings, recommendations and concluding remarks of the research study. The research study was conducted on the notion that alternative conceptions about the concept of energy and the principle of conservation of mechanical energy are commonly found among Grade 10 learners in South African schools (Wesi, 2003:248). The research study also focused on a constructivist teaching-learning approach that can be used to reform, reconstruct or build upon learners' conceptions relating to the principle of conservation of mechanical energy (Trumper, 1991:6; Trowbridge *et al*, 2002:224; Scott *et al*, 1991:7). It is on the basis of these notions that an action research methodology was used for the study as reflected in paragraph 4.2.

The study was done by means of a literature review and empirical study. The literature review entails and consists of scientific and alternative conceptions of energy as well as constructivist instructional strategies. The empirical study outlines the research design and methodology of the study. The discussions in this chapter will be based on the findings and the results of the empirical evidence of the research study.

6.2. The scope of the research study.

This is a small-scale study done in one class in a particular school (see paragraph 1.4) of which it can be argued that the findings of the research study may not be generalized to other schools. However, the study can be used as a tool by teachers to research their own practices so as to improve, be abreast with and adapt to current and contemporary trends in the teaching and learning environment. The intention of the study in this regard is to find out and verify the nature of alternative conceptions of grade 10 learners regarding the concept of energy and conservation of mechanical energy as discussed in paragraph 2.3.2.

The scope of the content is limited only to the concepts relating to the principle of conservation of mechanical energy as a build-up to other concepts in mechanics (e.g. momentum) as well as in other fields (e.g. electrical potential, internal energy, etc.) The concepts relating to the principle of conservation of mechanical energy are regarded as core knowledge in grade 10 and across other grades (grade 11 and 12) in the FET band as outlined in paragraph 3.2.2.

The intervention that forms part of the empirical study was designed in accordance to the principles of content progression and context integration as required in the NCS (see paragraph 3.2). According to Nieuwoudt and Beckley (2004:324), the effectiveness of an OBE learning programme is enhanced if the designer applies these two curriculum principles correctly. The results of the empirical study (paragraph 5.6) indicate the effectiveness of the intervention.

6.3 The research findings of the empirical study.

Learners' alternative conceptions were diagnosed and revealed by the results of the pre-test (table 5.1 and 5.2). The diagnosed and revealed conceptions were treated and remedied by using an inquiry-based approach during the intervention stage that adhered to the OBE principles of progression and integration (paragraph 4.6). The results of the post-test (tables 5.3 and 5.4) as well as the high learning gain show the accomplishment of the aims of the study (paragraph 1.2), namely to effectively improve grade 10 learners' understanding of concepts relating to the principle of conservation of mechanical energy (in a closed system).

The research findings are categorized and analysed according to two stages namely, pre-test and post-test results. The analysis of the pre-test results (paragraph 5.3) of the empirical study conducted confirms that the learners used for the study had alternative conceptions regarding the concepts relating to the conservation of mechanical energy similar to those found in physics education research (paragraph 2.4 and 2.5). Their alternative conceptions correspond with those given in the literature (e.g. Watt, 1983:213; Wesi, 2003:260), for example, association of energy with living things and motion, energy expenditure, energy as a fuel, etc. This observation might mean or could be generalized as a common trend of alternative

conceptions found in or held by secondary school learners in South Africa regarding concepts relating to energy and conservation of mechanical energy.

The analysis of the post-test results (paragraph 5.5) shows an improvement in the learners' conceptual understanding of concepts relating to the conservation of mechanical energy as reflected in tables 5.1 and 5.3. These concepts include the science concepts of energy, kinetic energy and potential energy. The analysed learners' responses also show that learners were able to indicate and note energy transformations taking place in the system (see paragraph 5.5). The learners' progress was recorded. For example, energy was recognized and regarded as the property of matter (both living and non-living) by most of the learners. Learners also noted relative positions of objects as an indication of potential energy.

In the study conducted, the progress of grade 10 learners (target population) was evident in the analysis of the post-test responses of learners (paragraphs 5.5.1, 5.5.2 and 5.6) after the intervention was conducted. The progression in thinking for the learners regarding the concepts relating to the principle of conservation of energy could be attributed to the advancement and development of cognitive skills and knowledge. The abstract thinking and knowledge of the learners became more advanced, refined and developed.

The pre-test results (paragraph 5.3) and learners' responses to questions during the intervention (paragraph 5.4), showed that the learners did not have much problems with the concept of kinetic energy. This may be due to their association of energy with motion in everyday life (Watt, 1983). Although they did not reveal a good understanding of potential energy, some learners referred to objects' ability to move in the pre-test. This can be a starting point for introduction of the science concept of potential energy. According to the constructivist theory (paragraph 3.3.1), the teacher should link onto learners' existing knowledge.

Learners who do not have a thorough understanding of the science concept of gravitational potential energy, cannot understand the principle of conservation of mechanical energy. If energy is only associated with motion, an objects' energy is "created" when it moves faster, and "lost" when it slows down (refer to learners' responses to item 2.3, paragraph 5.3.4). From

these results follow that learners' knowledge regarding mechanical energy should progress from the concept of kinetic energy, to potential energy and transformations between these two energy forms, to the principle of conservation of mechanical energy. This order was followed for the activities of the intervention (paragraph 5.4).

The normalized learning gain of 0.68 obtained when the results of the questionnaire were processed is high, which indicates a high effectiveness of the intervention (Hake, 2002). However, the motivations given by the learners for their responses show that many of the learners hold intermediate concepts (Kaper & Goedhart, 2002) such as the perception of potential energy as stored energy. The idea of potential energy as stored energy is prescribed as core knowledge in the NCS for the natural sciences for grades R to 9 (Department of Education, 2002) and presented as such in GET textbooks. This perception of potential energy can give rise to new alternative conceptions, as is evident from the results of the empirical study. For example, the alternative conception that no non-living object possesses energy can be replaced with the alternative conception that all non-moving objects possess potential energy (irrespective of their position relative to other objects). Learners have to proceed towards a more scientific understanding of the concept of potential energy as a property of a system and due to relative positions of objects or charges in each other's force fields (paragraph 2.2). This can only be accomplished by the association of the concept with the scientific concepts of work and force.

The learners' conceptual change, improved understanding and learning progression that was observed, noted and indicated could be attributed to the advantages and benefits of using an inquiry teaching-learning strategy in conjunction with other teaching-learning strategies, discussed in chapter 3 (paragraph 3.3), as a contemporary constructivist approach to teaching and learning.

The following was noted during the intervention stage of the research study as discussed in paragraph 4.6:

- Arranging learners into small cooperative groups allows them to share ideas and explanations with each other and promotes social interactions, communication skills and optimal participation.
- Sequential planning of lessons can help a teacher *note* or *see* in advance the line of progression needed for learners' optimal gains in terms of learners' understanding of the concept to be taught and learnt.
- Integration of laboratory and everyday experiences enhances learning.

6.4. Recommendations.

It is recommended that, when teaching the principle of conservation of mechanical energy, the first activity the teacher has to do is to diagnose learners' alternative conceptions of related concepts (e.g. potential energy and energy transformations). The importance of the pre-test is to diagnose the existing knowledge of the learners before introducing a new topic. The reason for administering the pre-test is because the core knowledge, energy, is not specified clearly in the GET band (paragraph 3.2.3). This also provides guidelines and directives on how to plan and design effective teaching and learning experiences for the learners. In this way the constructivist principle stated by the Ausubel and Piagetian elements of teaching and learning are adhered to. This constructivist approach to teaching and learning broadens and builds on learners' pre-knowledge and progressively refines it towards the scientific conceptions. The instructional implications of using constructivist teaching and learning strategies are highlighted and discussed in chapter 3 of the research study.

Although the limitations of the research are cited and stated in paragraph 6.2, the research study can offer and provide some ideas about how to effectively teach the conceptually difficult concepts relating to conservation of mechanical energy in grade 10 using the available resources. The constructivist approach to teaching, as discussed in paragraph 3.1, presents a challenge to teachers to be creative, innovative and resourceful when introducing and teaching new and difficult science concepts, like energy, to learners.

On basis of this and other research studies (Redish, 2003:43; Trumper, 1990:353) it can be recommended that the following steps are followed:

- Start from what learners already know.
- Treat learners' alternative conceptions with the urgency they require so that learners do not carry them to the upper or next classes.
- Employ constructivist teaching-learning approaches (e.g. inquiry teaching- learning strategy) to promote conceptual change and understanding.
- Create a list of terms with definitions in order to foster learners' understanding of requisite scientific terminology.
- Relate the scientific knowledge that is being taught to its application in real life situations.

Teachers may also use ideas from this study to research their own practice as well as to design learning and teaching experiences and materials for effective and meaningful learning and teaching (Department of Education, 2003:5). The value of researching one's practices as a teacher is the ability to be kept abreast with the dynamic nature of the teaching and learning environment.

6.5. Final conclusions.

The hypothesis of the study was proved to be valid, i.e., Grade 10 learners hold alternative conceptions relating to the principle of conservation of energy that can be remedied effectively by means of an inquiry-based teaching-learning sequence that adheres to the OBE principles of progression and integration.

In conclusion, the constructivist teaching-learning approach puts more emphasis on the learning process rather than on the teaching process. The emphasis is towards learner-centred learning, i.e., an approach to education in which the teacher's role is less that of an expert and more that of a skilled facilitator. Also, content that is derived from and taught within a context that is familiar and accessible to learners as well as the use of contemporary constructivist teaching and learning approaches (e.g. inquiry teaching-learning strategies as used in the

research study) could play a pivotal role in strengthening a learner-centred learning environment favourable for both the learner and the teacher.

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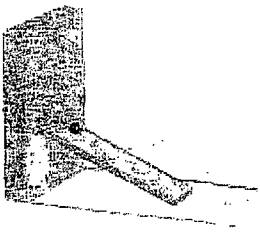
APPENDIX A




QUESTIONNAIRE ON THE CONCEPT ENERGY AND CONSERVATION OF MECHANICAL ENERGY.


NAME: _____ GENDER: _____
 SCHOOL: BAKOLOBENG. H.S. GRADE: 10C
 AGE: _____ DATE: _____

PART 1.

Look at the pictures carefully. Cross the YES column if you think the statement accompanying the picture is correct or the NO column if you think the statement accompanying the picture is wrong. If you are not certain whether the statement is correct or wrong, cross the UNCERTAIN column.

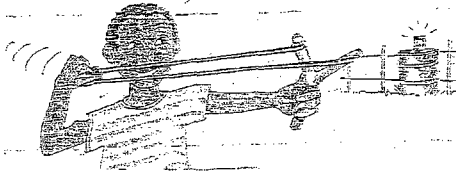
Statement and picture	Cross one column			Give reason for your choice
	Yes	No	Uncertain	
1.1. A ball resting on top of a table as shown in the picture has energy. 				
1.2. A ball resting on a slope has energy. 				

	Yes	No	Uncertain	
<p>1.3.A ball speeding as it goes down a slope gains energy.</p> 				
<p>1.4.A cat sitting as shown in the picture has energy.</p> 				
<p>1.5.Rubber bands of the catapult as shown in the picture have energy.</p> 				

	Yes	No	Uncertain	
<p>1.6.The strings of the bow held stretched by the girl in the picture have energy.</p> 				

PART 2.

The boy in the picture is practicing target shooting with his catapult. He is aiming at a tin placed on top of a drum.



INSTRUCTIONS

Respond to the questions by making a cross on the appropriate box of your choice and give a reason to support your choice.

2.1. Does the stone inside the catapult have energy?

Yes / NO

Give a reason _____

2.2. The stone is fired towards the target (tin). Does the fired stone have energy while it is in the air?

YES / NO

Give a reason _____

2.3. Has energy been created by the catapult?

YES / NO

Give a reason _____

2.4. Does the target (tin) possess energy before it is hit?

YES / NO

Give a reason _____

2.5. Does the stone do work on the tin when it hits it?

YES / NO

Give a reason _____

2.6. Is energy lost when the stone hits the tin?

YES / NO

Give a reason _____

2.7. The target is hit and falls down. While falling does the target have energy?

YES / NO

Give a reason

APPENDIX B

LESSON PLAN: PHYSICAL SCIENCE

Subject: Physical science	Grade: 10
Lesson plan No: 01	No. Of activities: 03
Duration of the lesson: 1hour	Week/date: 17/04/07

Content: Mechanics						
Context: Energy and principle of conservation of mechanical energy						
Activities	1.1		1.2		1.3	
Los and ASs	LOs	ASs	LOs	ASs	LOs	ASs
	1	1-4	1	1-4	1	1-4
	2	1,2 & 4	2	2	2	1,2 & 3
	3	1				
Details of activity	<ul style="list-style-type: none"> ➤ Individually learners use their textbooks to write the definitions of the terms kinetic and potential energy. ➤ Learners roll balls on the floor and refer to the definitions of the terms to identify energy possessed by the rolling balls (group work). 		<ul style="list-style-type: none"> ➤ Individually learners raise and hold the shot-put ball and brick with an outstretched arm at different heights (knee, waist and shoulder height). ➤ Learners record and note the height(s) where the ball and or the brick become difficult to balance. 		<ul style="list-style-type: none"> ➤ Group work- masses of the two balls and brick are measured and recorded. ➤ The raising act in act. 1.2 is once more repeated. ➤ Comparisons and observations are noted and recorded. ➤ Reports are written. ➤ Discussions are entertained. ➤ Conclusions are drawn. 	

		<ul style="list-style-type: none"> ➤ Group discussions from observations. ➤ Identify the form of energy possessed by the objects by referring to the definitions. 	
Teaching method and approach	Inquiry, co-operative learning, direct instruction		
Assessment strategies	Self, peer, group, teacher.		
Forms of assessment	Work sheets, homework, group discussions, presentations, class work.		
Resources	Textbooks, balls (shot-put and soccer), brick and mass scale.		
Teacher reflections	<ul style="list-style-type: none"> ➤ Evaluating learners' responses. ➤ Providing feedback on their responses. ➤ Motivate and encourage learners to participate. ➤ Provision of additional support. 		

--APENDIX B

LESSON PLAN: PHYSICAL SCIENCE

Subject: physical science		grade: 10
Lesson plan no: 03		Number of activities: 04
Duration of the lesson: 45 MINUTES		week/date: 25 APRIL 2007
Context: Mechanics.		
Core content: Energy and principle of conservation of mechanical energy.		
	Activity 1.1	Activity 1.2
Learning outcomes and assessment standards.	LO 1, AS 1,2,3 &4 LO 2, AS 1,2&3 LO3, AS 2 & 3	(a) Group activity (b) Discussions and work sheets provided
Integration with other subjects.	None	None
Detail of the activity.	<ul style="list-style-type: none"> ➤ You will be given two balls of different masses (shot-put ball and soccer ball). ➤ A ramp with rails. ➤ A measuring tape. ➤ Set up the apparatus as shown in the picture. 	<ul style="list-style-type: none"> ➤ Measure the masses of the two balls given. ➤ Drop each ball from the ramp and measure the distance each ball traveled at the end of the ramp. ➤ Record all your results. ➤ Change the elevation of the ramp and repeat the activity. ➤ Record all your results. ➤ Compare and analyze your results. ➤ Draw conclusions from your results. ➤ Report your results to other groups.

Teaching method and approach.	Inquiry in the laboratory. 5E instructional model	Inquiry in the laboratory. 5E instructional model.
Assessment strategies.	Self Peer Group Teacher	<ul style="list-style-type: none"> ➤ What form of energy does the ball have at the top of the ramp? ➤ Why do balls roll down the ramp? ➤ What two kinds of energy does a ball have half way down the ramp? ➤ How can you tell which ball had the most kinetic energy at the bottom of the ramp? ➤ If these two balls fell on your toe, which one will hurt you the most and why? ➤ Name two quantities that you think determines how much kinetic energy a moving object has?
Resources.	Two ball (shot-put and soccer ball) Mass scale Measuring tape A ramp	
Teacher reflection.	<ul style="list-style-type: none"> ➤ Evaluating learners' responses. ➤ Presenting conflicting 	

	situations. ➤ Giving feed back on learners' responses.	
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APPENDIX B

RESEARCH PROJECT

Subject: Physical science

Grade: 10

Submission date: 11 May 2007

Content: Mechanics

Context: Energy and principle of conservation of mechanical energy.

LEARNING OUTCOMES	ASSESSMENT STANDARDS
1.	1-4
2.	1,2&3
3	1&2

Topic: Application of the concept of energy and principle of conservation of mechanical energy.

Observations: Write down your observations.

Take pictures.

Record situations where the concept and principle are applied.

Interpretations: Use your background knowledge of the concept of energy and principle of conservation of mechanical energy to write a report on the data collected and recorded.

Presentation: Present your findings, observations, data collected and recorded to the class.