List of tables

List of figures

CHAPTER 1

RATIONALE OF THE STUDY

1.1 Introduction

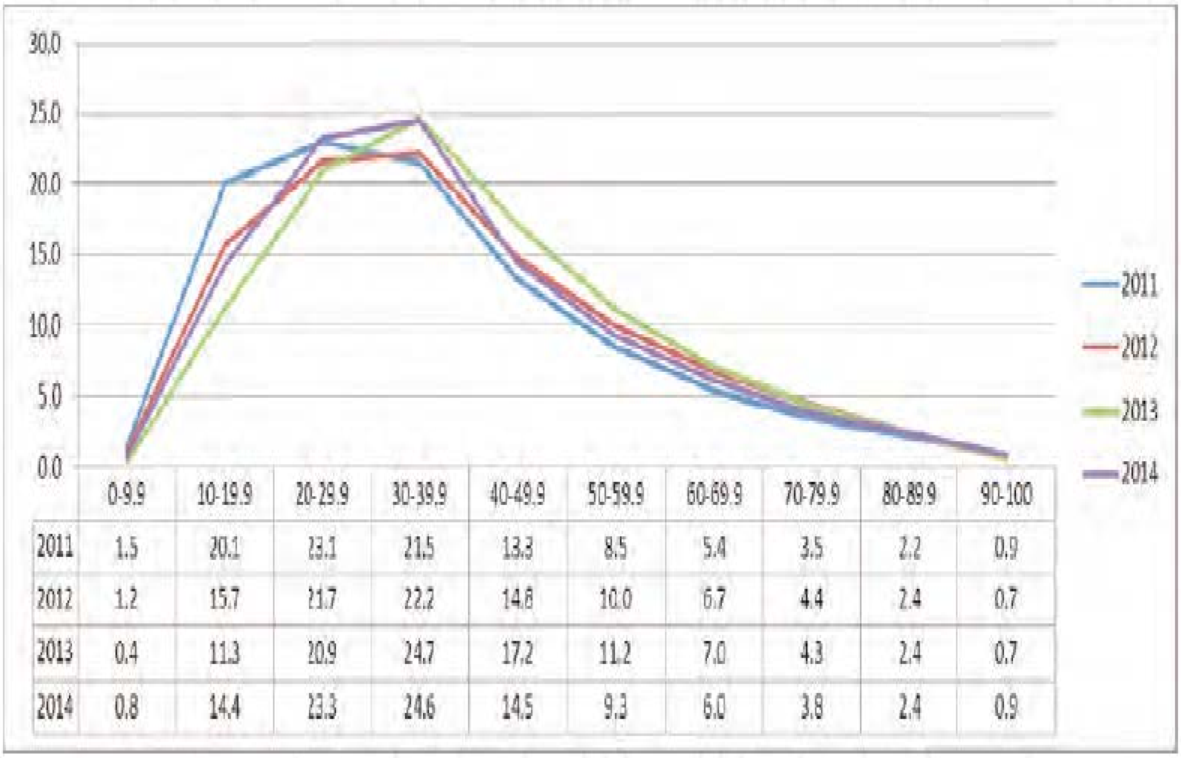
This study focuses on the application of a conceptual change approach to teach the principle of conservation of mechanical energy in Physical Sciences. The introductory chapter provides the rationale for the study by presenting the background of the study, as well as the state of science education both nationally and provincially. It also introduces research questions that will be answered in order to address the research problem. This chapter, also, highlights the significance and limitations of the study and provides an overview of the structure of the thesis.

1.2 Background of the study

1.2.1 National, provincial, district and school

There have been many reforms introduced in the curriculum since the dawn of democracy in South Africa. In 1998 the curriculum changed from NATED 550 to curriculum 2005 (C2005), popularly known as Outcomes Based Education (OBE). C2005 was progressively rolled out in stages in the General Education and Training (GET) band from Grade1 in 1998 to Grade 9 in 2002. C2005 did not stay long because of its difficult jargon and the confusing role of a teacher who was now a mediator in the learning process. From 2004 to 2007 the Revised National Curriculum Statement (RNCS) was introduced in schools but was also not popular among teachers because it was vague as far as content was concerned, and was cumbersome to teachers because of too much administrative work involved. In 2008 the National Curriculum Statement (NCS) was introduced to schools in the FET phase but still lacked depth in content. From 2011 to 2014 NCS has been revised to Continuous Assessment and Policy Statement (CAPS). The resistance to change by the teachers due to the substandard training in the new curricula that teachers received from the subject specialists, including Physical Sciences ones, left much to be desired. Be that as it may content in Physical Sciences and the teaching approaches to suit the new curriculum changed in all the Grades.

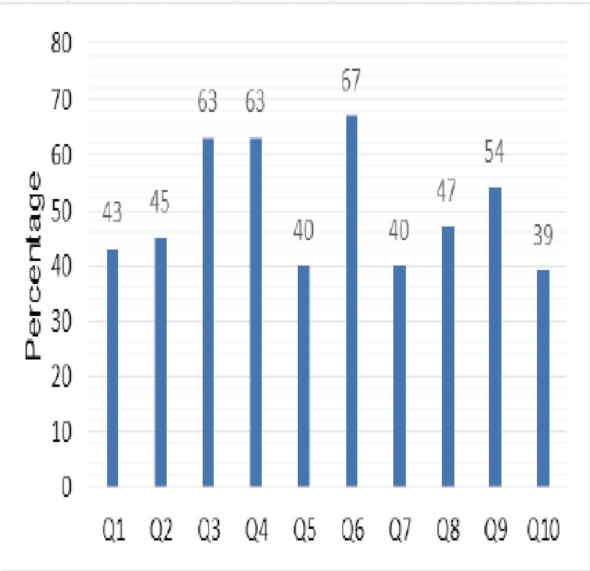
Curriculum reform amplified existing teaching problems in the education department nationwide. This was evident in learner performance in an exit point like Grade 12, the end of the Further Education and Training (FET) phase. Poor learner performance was evident in all the subjects. Learner performance in subjects like Physical Sciences was poor; in 2009 the lowest national pass percentage of 29% was witnessed. The Grade 12 end of the year results of Physical Sciences over the past four years have been analysed in the table below and they show that on average less than 25% was obtained by the learners in Physical Science.



	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-100
2011	1.5	20.1	23.1	21.5	13.3	8.5	5.4	3.5	2.2	0.9
2012	1.2	15.7	21.7	22.2	14.8	10.0	6.7	4.4	2.4	0.7
2013	0.4	11.3	20.9	24.7	17.2	11.2	7.0	4.3	2.4	0.7
2014	0.8	14.4	23.3	24.6	14.5	9.3	6.0	3.8	2.4	0.9

Figure 1: Graph of the performance distribution curve in Physical Science:

A detailed analysis of how learners performed in the past four years per topic in the first paper (Physics) is represented in Figure 2 below.



Q1	Multiple choice questions
Q2	Newton's laws of motion
Q3	Vertical projectile motion
Q4	Momentum
Q5	Work, energy and power
Q6	Doppler effect
Q7	Electrostatics
Q8	Electric circuits
Q9	Motors, generators and alternating current
Q10	Photo-electric effect

Figure 2: Graph of average marks per question expressed as percentage: Paper

Question 5 was on Work, Energy and Power and was performed poorly over the past four years with an average of 40%. The basis of question 5 is the Principle of Conservation of Mechanical Energy taught in Grade 10. It is generally considered that teachers are responsible for the poor performance of learners given that most FET teachers are under-qualified. Some teachers lack content knowledge and/or the appropriate teaching approach that will put the message across to iron out existing misconceptions.

The teacher content gap was highlighted as one of the causes of the drastic downfall in learner performance in Government reports (DBE, 2013). According to the report some of the teachers had a content gap because they were under-qualified, more especially in the FET phase, and needless to say, in subjects like Physical Sciences. Also, the content in the new curriculum was challenging as in-depth knowledge of subject content was required. This problem was identified by the Department of Basic Education (DBE) and consequently teachers were trained in all the provinces, including the Eastern Cape Province.

Despite all the concerns cited above, Physical Sciences is one of the subjects a learner can choose at the beginning of the Further Education and Training (FET) phase which starts from Grade 10 to Grade 12. It is in Grade 10 where learners choose subjects relevant to careers that they will follow later on in life. Physical

Sciences is a subject that can open up quite a number of career paths that a learner could pursue.

The subject, Physical Sciences, is divided into Physics (Paper 1) and Chemistry (Paper 2). When learners are assessed in the two papers, they perform poorly in Paper 1. Consequently, the overall performance in the subject is affected negatively. The National Curriculum Statement (NCS) national examiners' reports over the past four years showed that learners performed poorly in Paper 1 because of a dismal performance in some knowledge areas like Mechanics. In the Eastern Cape Province and districts the same trend was witnessed as shown in Table 1 below.

Table 1: Pass rate in Physical Science (%-age form)

Year	2011	2012	2013	2014
National	53,4	61,3	67,4	61,3
Provincial	46	50.4	55,8	51,5
District	74,8		71,5	63,4
School	93	97,1	96.2	95,4

1.2.2 Context of the study

The study is conducted in the Eastern Cape Province, in a small rural district of Cofimvaba in school X. School X is a Senior Secondary School starting from Grade 10 to Grade 12. It is a mixed school that consists of 80% girl learners and 20% boy learners. About two thirds of the learners in the school do Physical Sciences. These learners are taught by three teachers who also teach other subjects in the school. There are three Physical Sciences classes in Grades Ten and Eleven. Grade Twelve has two Physical Sciences classes only. The language of teaching and learning for Physical Sciences is English. The Home Language of all the learners is isiXhosa. English is not the Home Language for the Physical Sciences teachers either.

The school is situated right in town. Learners registered in the school come from the feeder schools around town and also from the neighbouring districts. Learners choose school X because it has a boarding facility and the community believes that the quality of education in school X is better than in many other schools in that area. Although school X is in town, its learners come from informal settlements surrounding it. These are the learners who come to school with hungry stomachs and social problems. This area is meant for low income people and some of them are unemployed. There is also a low percentage of child-headed households. The CAPS document and the examination guidelines for Physical Sciences are adhered to by the teachers. There is an assessment plan in place determining when formal and informal activities are conducted. Extra classes are conducted to ensure that the work is covered within the stipulated time. The hindrance to meaningful teaching is an under-resourced school. Despite all that, the school has two, fully equipped computer laboratories with sixty-two computers for teaching and learning. Learners and teachers have gadgets like tablets because the school is in the ICT4RED project and computers were donated to them.

The researcher is a Physical Sciences teacher with more than twenty years' experience in teaching Physical Sciences in Grades 10, 11 and 12. She teaches in this rural high school X of the Eastern Cape where most teachers are still using the traditional teaching strategies to teach the different subjects including Physical Sciences. The researcher has taught Physical Sciences during the time of NCS and in the current Curriculum and Assessment Policy Statement (CAPS) integrating the traditional and contemporary teaching strategies. Three Grade 10 Physical Sciences classes in School X are taught by two teachers. In 2015 the researcher taught one Grade 10 Physical Sciences class and the other two classes were taught by the second teacher. In the 2015 subject improvement plan for Physical Sciences the researcher completed a question by question analysis form of 2014 Physics end of the year Grade 10 examinations. The Principle of Conservation of Mechanical Energy was one of the sub-topics in Mechanics in which learners performed dismally. During moderations at cluster level, it was evident that learners from other schools did not do well either in this topic. These findings directed the researcher to consider what needs to be done to improve learners' marks in this section of Physics. The picture witnessed after doing the subject analysis in school X provides the same picture that was witnessed in the cluster meeting where other schools in the district also presented their subject improvement plans.

1.3 State of science education in South Africa

The World Economic Forum's (WEF) Global Information Technology Report (2014) painted a very bleak picture of the state of Science Education in South Africa. A report

(DBE, 2013) confirms firstly that there is a shortage of qualified Physical Sciences teachers and it is problematic that the Department of Basic Education does not even know the exact number of Physical Sciences teachers in the system. Secondly, the same report also shows that teachers are not trained adequately by universities. Thirdly, there are no long-term professional programmes for science teachers that are already in the system. Fourthly, the lack of an intelligible incentive scheme to retain skilled and dedicated Science teachers play a role in the poor quality of Science Education in South Africa. Fifthly, the private sector offers Physical Sciences teachers better salaries and benefits and that is how some teachers are drained from the system. The exodus of science teachers due to greener pastures has caused a big shortage of Physical Sciences teachers. Lastly, the district officers do not provide adequate support to these teachers.

Poor teaching or learners without a teacher affect the way those learners will perform in that subject. This situation leads to reports about the quality of Mathematics and Science where, for example, the quality of South African education was placed last out of 148 countries in the Global Competitiveness Report for 2014-2015 published by the World Economic Forum. Standardised tests like Matric Examinations show poor Physical Sciences results nationally and that affect the overall results. Numbers of candidates in Grade 12 writing Physical Sciences are declining as shown in the table below:

Table 2: A decline in the number of grade 12 learners writing Physical Science

LEVEL	2011	2012	2013	2014
National	180 585	179 194	184 383	167 997
Provincial (E.C.)	26 367	25 603	25 218	20 694

Very small numbers of African candidates obtain university entrance in Mathematics and Physical Sciences. For those entering for first year Physics, their performance show that they were poorly prepared (reference). Consequently, South Africa has a shortage of critical skills owing to the low standard of Science Education. To rescue the situation DBE has collaborations with Science Faculties in the different universities. There are intervention programmes in place funded by businesses and other stakeholders that DBE forms partnership with.

1.4 Interventions in Science Education in South Africa and the Eastern Cape Province

South Africa is in a precarious state as far as Science Education is concerned. The Government, in partnership with the private sector and non-profit organisations took upon themselves to rescue the situation. The following intervention strategies were put in place to improve learner performance in Mathematics and Physical Sciences:

1.4.1 Dinaledi Schools Project

The Dinaledi Schools Project is an initiative providing support to selected high schools in Mathematics and Physical Sciences. Focus areas were learners, teachers, development of learning environment, and teacher education and development. The specific objective of the project was to raise performance and participation of disadvantaged learners in Mathematics and Physical Sciences. The World Bank conducted an impact evaluation study that revealed that the Dinaledi Schools' Project yielded noticeable enrolment and performance results in Physical Sciences. At the initiation of the project in 2001 a hundred schools were piloted nationwide although the project has now been rolled out to more than 500 schools.

1.4.2 Adopt a school programme

The 'adopt a school' programme is a sub-project of Dinaledi Schools Project where private partners could assist the department. In this programme Standard Bank adopted 114 Dinaledi schools and the Department of Science and Technology adopted 18 Dinaledi schools. Standard Bank contracted Deloitte and Touche to do the needs analysis for the adopted schools and schools were supported with physical resources. Unfortunately, the partnership of Standard Bank and the Government was binding for three years only.

1.4.3 The South African Agency for Science and Technology Advancement (SAASTA) education unit

SAASTA is an agency for the National Research Foundation. Its education unit supports school science including teacher and learner programmes; science enrichment projects and competitions. SAASTA funds and coordinates National Science Olympiads and the National Science Week which run annually during the first week of August. The unit is also involved in the Primary School Science Intervention (PSSI). They are devoted to promoting science in primary schools. The intervention is aimed at kindling the interest in and understanding of Mathematics and Science among young learners. SAASTA also features in the role modelling campaign. This campaign exposes learners to career opportunities in Mathematics, Science and Technology, and gives learners an opportunity to interact with appropriate role models in Science, Engineering and Technology (SET) careers.

1.4.4 Repackaging of the curriculum

The repackaging of the NCS curriculum, commonly known as Curriculum and Assessment Policy Statement (CAPS) was initiated in 2012. The aim of repackaging the curriculum was to provide more specific content for teachers, so that they knew what to teach, and at what stage to teach it. Physical Sciences curriculum overload at Grades 10 to 12 was addressed through the current CAPS process.

1.4.5 University of the Western Cape (UWC) project for FET Science Educators

The Science Learning Centre for Africa (SLCA) in UWC supports the programme for science teachers in the rural Eastern Cape on content knowledge, practical teaching and science clubs' initiatives. About fifty FET Physical Sciences teachers in the Eastern Cape were trained by UWC and qualified in ACE in FET Science. The same cohort of teachers further studied with UWC through distance learning doing Honours in Science Education and are currently studying towards the Masters level with the same university. In the same programme, another cohort of senior phase Natural Science teachers have recently been trained for a week on matter and materials.

1.4.6 Mathematics Skills Upgrade Programme (MathsUP) and Science Skills Upgrade Programme (SSUP)

210 Mathematics teachers and 50 Physical Sciences teachers teaching Grades 11 and 12 attended two short learning programmes (MathsUP and SSUP) through Nelson Mandela Metropolitan University (NMMU). These accredited courses were funded by the Education, Training and Development Practices (ETDP) Seta and the Provincial Department of Basic Education. Each participating teacher received a laptop with the Touch Tutor package and additional support material, all pre-installed. A second group of teachers is being trained, starting from 2015.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In keeping with the purpose of the study to investigate the effect of teaching the Principle of Conservation of Mechanical Energy using the conceptual change strategy, this chapter reviews existing literature regarding the effect of using the conceptual change teaching strategy to teach Physics concepts.

The first section of the literature review highlights the theoretical framework on which this study is based. They are constructivism and the conceptual change theories. The second section of the literature review focuses on the correct ways of teaching Energy concepts. The third section shows how this study fits in international and national Physics Education that is already there. After giving a detailed context of the study, the last section gives account of the significance of the topic under study. (Henning et al.:2004) reaffirm the three purposes of literature reviews as:

- The literature review is used first and foremost in the contextualisation of one’s study, to argue a case and to identify a niche to be occupied by one’s research.
- Secondly the literature review is also used to synthesise the literature on the selected topic and to engage critically with it.
- The third instance where literature reviews are useful is where you explain the data and show the relevance of your findings in relation to the existing body of literature.

2.2 Theoretical Framework

The study is underpinned by the theory of constructivism and the conceptual change theory (Posner, Strike Hewson, Gertzog, 1982).

2.2.1 Constructivism

The meaning of constructivism varies according to one's perspective and position. Within the educational contexts there are philosophical meanings of constructivism, as well as personal constructivism as described by Piaget (1967), social constructivism outlined by Vygtosky (1978), radical constructivism advocated by von Glasersfeld (1995), constructivist epistemologies, and educational constructivism

(Mathews, 1998). Social constructivism and educational constructivism (including theories of learning and pedagogy) have had the utmost impact on instruction and curriculum design because they seem to be the most beneficial to integration into current educational approaches. Below is the dissimilarity of definitions for constructivism in education.

(The mind can) "put together those ideas it has, and make new complex ones." (Lock, 1947).

"It is assumed that learners have to construct their own knowledge-- individually and collectively. Each learner has a tool kit of concepts and skills with which he or she must construct knowledge to solve problems presented by the environment. The role of the community, other learners and teacher is to provide the setting, pose the challenges, and offer the support that will encourage mathematical construction." (Davis, Maher, Noddings, 1990)

"Constructivism is not a theory about teaching…it is a theory about knowledge and learning the theory defines knowledge as temporary, developmental, socially and culturally mediated, and thus, non-objective."(Brooks & Brooks, 1993)

"Knowledge, no matter how it be defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her own experience." (von Glasersfeld, 1995)

"The doctrine itself holds that 'language users must individually construct the meaning of words, phrases, sentences and texts.'" (Suchting, 1998; von Glasersfeld, 1989)

"Constructivists allege that it is we who constitute or construct, on the basis of our theorizing or experience, the allegedly unobservable items postulated in our theories." (Nola, 1998)

"The central principles of this approach are that learners can only make sense of new situations in terms of their existing understanding. Learning involves an active process in which learners construct meanings by linking new ideas with their existing knowledge." (Naylor & Keogh, 1999)

"Constructivists of different persuasion (hold a) commitment to the idea that the development of understanding requires active engagement on the part of the learner." (Jenkins, 2000)

One of the common cobwebs of constructivism that runs transversely all these definitions is the idea that development of understanding requires the learner to actively engage in meaning-making. In contrast to behaviourism, constructivists argue that "knowledge is not passively received but built up by the cognizing subject" (Von Glasersfeld, 1995). Thus, constructivists alter the focus from knowledge as a product to knowing as a process.

Constructivism is relating to knowledge acquisition and putting more emphasis on knowledge construction rather than knowledge transmission and the recording of information conveyed by others. Constructivism recommends that learner impressions of knowledge are derived from a meaning-making quest in which learners engage in a process of constructing individual interpretations of their experiences. The role of the learner is comprehended as one of constructing and altering knowledge. But what does it mean to construct knowledge? Within constructivism there are different views of the nature of knowledge and the knowledge construction process. Moshman (1982) has identified three types of constructivism: exogenous constructivism, endogenous constructivism and dialectical constructivism.

In exogenous constructivism, as with the philosophy of realism, there is an external reality that is reconstructed as knowledge is formed. Thus one's mental structures develop to reflect the organization of the world. The information processing conceptualizations of cognitive psychology emphasize the representation view of constructivism, calling attention to how we construct and elaborate schemata and networks of information based on the external realities of the environments we experience.

Endogenous constructivism or cognitive constructivism (Cobb, 1994; Moshman, 1982) centres on internal, individual constructions of knowledge. This perspective, which is derived from Piagetian theory (Piaget 1977, 1970), emphasizes individual knowledge construction kindled by inner cognitive conflict as learners attempt to find a solution for mental disequilibrium. Essentially, children as well as older learners must negotiate the meaning of experiences and phenomena that fail to correspond to their existing schema. Students may be said to create their own knowledge, refining their cognitive structures by revising and creating new understandings out of prevailing ones. This is achieved through individual or socially mediated discovery-oriented learning activities.

Dialectical constructivism or social constructivism (Brown, Collins, & Duguid, 1989; Rogoff, 1990) interprets the origin of knowledge construction as being the public place where people meet, interact by sharing, comparing and debating among learners and mentors. Through a highly interactive process, the social climate of learning is granted centre stage and learners both polish their own meanings and help others find meaning. This is how knowledge is mutually built.

This opinion is a direct reflection of Vygotsky's (1978) sociocultural theory of learning, which highlights the supportive guidance of mentors as they enable the apprentice learner to achieve more complex skills one after another, understanding, and in the long run acquire acceptable skills.

The primary nature of social constructivism is concerted social interaction as against individual investigation of cognitive constructivism. Through the cognitive give-and-take of social interactions, one constructs personal knowledge. In addition, the context in which learning occurs cannot be detached from emergent thought. This latter view known as contextualism in psychology becomes a significant principle of constructivism when expressed as positioned cognition. Social constructivism apprehends the most universal existing perspective on constructivism with its emphasis on the importance of social interactions for cognitive growth and the impact of culture and historical background on learning.

"While there are several interpretations of what [constructivist] theory means, most agree that it involves a dramatic change in the focus of teaching, putting the students' own efforts to understand at the centre of the educational enterprise" (Prawat, 1992). Even with the differences outlined above, there is important resemblance among most constructivists with regard to four central characteristics believed to influence all learning: 1) learners construct their own learning; 2) the dependence of new learning on students' existing understanding; 3) the critical role of social interaction and; 4) the necessity of authentic learning tasks for meaningful learning (Bruning, Royce, & Dennison, 1995; Pressley, Harris, & Marks, 1992).

All of the above characteristics stimulating learning in constructivism will be taken into consideration in the methodology of this study. For example, during the intervention stage, the lesson plan will be designed such that it addresses the teaching and learning strategies used in reconstructing existing knowledge so that learning can make meaning by using genuine learning tasks in the process.

Today learners come to the Science class with their own ideas, beliefs, and understanding of how things work (Robottom, 2004). Therefore, learning is not to fill the learner’s head with information and data, but to change or work with their existing ideas and beliefs. Learning is seen by Robottom (2004) as conceptual change. The existing concepts included in the conceptual change theory are the pre-concepts learners acquired through interaction with other people from the world they live in, i.e. meaning their social context.

For the learner to construct meaning, he must actively strive to make sense of new experiences and relate it to what is already known or believed about a topic. Students develop knowledge through an active construction process, not through the passive reception of information (Brophy, 1992). In other words, learners must build their own understanding. How information is presented and how learners are supported in the process of constructing knowledge is of major significance.

Learners’ preconceptions that they bring to each learning task is emphasized too. Learners’ existing understandings provide the immediate context for interpreting any new learning. Irrespective of the nature or complexity of a learner’s existing schema, each person’s existing knowledge structure will have a powerful influence on what is learned and whether and how conceptual change occurs. For Tytler (1998): these conceptions in many cases form useful prior knowledge that a teacher can build on. In some cases, however, learners' "naive" conceptions can interfere with ideas we as teachers would want to develop. Learners' "alternative conceptions" have proved surprisingly difficult to change, and can compromise effective teaching.

2.2.2 The conceptual change theory

Over the past two decades, a number of authors have proposed models of classroom teaching for Science. Some of these models are described below. They were selected to represent a variety of methods to constructivist-informed teaching, but it is known that the list is by no means exhaustive. They are presented in chronological order and the authors' references to motivation have been identified. For the purpose of comparison, some of the classical or earlier models (i.e., the early 1980s to the early 1990s) will be described and analysed first, then some recent models (from the late 1990s onwards) will be examined thereafter.

There is no doubt that the most cited and most influential model of conceptual change was proposed by Posner, Strike, Hewson, and Gertzog (1982), which we will refer to as "PSHG" throughout this thesis. This model, which was mainly enthused by the Piagetian concept of accommodation (Piaget, 1968) and by the Khunian concept of "scientific revolution" (Kuhn, 1962), addresses the testing problem of making learners amend the "misconceptions" they hold about how the physical world operates.

Stella Vosniadou (2008) describes the "classical approach" of conceptual change as the primary paradigm that guided research and instructional practices in the classroom for many years. According to it, the learner is like a scientist, the process of (science) learning is a logical process of theory substitution, conceptual change is like a gestalt shift that happens over a short period of time, and cognitive conflict is the main instructional strategy for stimulating conceptual change (Vosniadou, 2008).

Among the models that belong to the classical tradition, Nussbaum and Novick's (NN) model of conceptual change is a convincing example (Nussbaum & Novick, 1982). This model proposes that teachers should (1) expose alternative frameworks, (2) create a conceptual conflict, and (3) encourage accommodation. The similar sequence was proposed in PSHG's model. In short, it suggested to (1) aggravate learners' dissatisfaction toward their own alternate conceptions by any means necessary (as in Nussbaum's "exposing event" [1982]), and then bring forth the scientific conception to learners in order for it to be (2) intelligible, (3) plausible, and (4) fruitful. According to the model, following these criteria would encourage learners to "replace" (Posner et al., 1982) their condemned non-scientific conceptions with the predetermined ones or, at least, accommodate them with the presented "discrepant events."

The sequence in which these pedagogical operations has to be conducted is not always clearly clarified, however most of the time dissatisfaction is presented as "the first crucial step" (Nussbaum & Novick, 1982). PSHG's and NN's models can be considered as ideal examples of the classical tradition of conceptual change, which has "cognitive conflict" as its central concept (Chan, Burtis, & Bereiter, 1997). It also became, to some degree implicit to almost the entire field that conceptual or cognitive conflict has to be the "first step to attain conceptual change" (Limon, 2001).

Scott also talks about the strategies "where conflict must be known by the learner in the early stages of teaching if learning is to happen" (Scott, Asoko, & Driver). The classical conceptual change approach involved the teacher making learners' alternative frameworks clear prior to designing a teaching approach consisting of ideas that are not appropriate for the learners' existing ideas and thereby promoting dissatisfaction (Duit & Treagust, 2003).

Following Dewey (1910), it is generally approved that accommodation demands first of all recognition by the learner of a problem and his inability to solve it with his existing conceptions (Nussbaum & Novick, 1982). Before an accommodation will occur, it is rational to suppose that an individual must have collected a store of unsolved puzzles or incongruences and lost faith in the capacity of his current concepts to solve these problems (Posner et al., 1982).

Many other models of conceptual change were subsequently proposed by authors in order to go outside the classical model tradition. Among the upcoming theorists (Carey, 1985; Chi, 1992; Thagard, 1992), some were mostly spinoffs (Hewson,1981) of the PSHG model, while others mainly provided analogies (Giordan, 1991). Some were quite difficult to comprehend (diSessa, 1993) or to practically apply (Vosniadou, 1994; Vosniadou & Brewer, 1992), while others were effective only in certain settings or were limited to certain content knowledge.

We believe that these "second-generation" models belong to what Ohlsson (2009) might describe as "transformation-of-previous-knowledge" models, that opposed the classical tradition by rejecting the idea that initial conceptions can be discarded. Furthermore, "not all of these second-generation models were developed to be applied to the context of school learning" (Limon, 2001). One cannot say that the models that followed were incompetent or uninteresting, or that they did not contribute meaningfully to the field; however, we believe that none of them reached enough teachers and researchers to become a leading model and replace the ones that belong to the classical tradition.

To construct a holistic picture of learning, it is both likely and beneficial to take into account a learning situation from more than one theoretical perspective of conceptual change. For example, rather than only considering conceptual changes in knowledge that a student constructs in moving from, say a pre- scientific notion to a scientific view of a concept, a more all-embracing and an enlightening picture would be painted if these changes were considered from a multidimensional perspective.

The way the learner gives an opinion about a concept in terms of its status (Posner, et al., 1982), its ontological category (Chi, et al., 1994) and the motivational and contextual factors (Pintrich, et al., 1993) can provide an all-inclusive picture of conceptual change. Consequently, a multi- dimensional framework making use of differing perspectives of conceptual change to view a learning situation has more value though the affective domain needs to be more fully explained. It appears to be most valuable to view the issue of motivation and interest in Science and Science teaching from the perspective of conceptual change. An important aim of Science instruction is to foster interest in much the same way as to develop learners' pre-instructional conceptions towards the intended Science concepts.

From the epistemological perspective, learners' conceptions are considered based on how they describe the concepts being investigated; whereas from the ontological perspective, learners' conceptions are viewed based on how they understand the nature of the concepts being investigated. This means that these epistemological descriptions and ontological considerations of learners on the concepts being investigated can form patterns in learners' conceptions (categories of conceptions). Thus, to identify and classify learners' conceptions, this study follows an inclusive perspective that involves students' epistemological descriptions and ontological considerations of concepts in the Principle of Conservation of Mechanical Energy.

Pintrich, Marx, & Boyle (1993) have found that learners' preconceptions can be extremely resilient and resistant to change, as demonstrated in Heather's story from the *A Private Universe*. A major criticism of the original conceptual change theory is that it presents an excessively rational approach to the learner learning, an approach that highlights and undertakes logical and rational thinking. Pintrich et al. refer to this approach as "cold conceptual change," because it overlooks the affective (e.g., motivation, values, interests) and social components of learning. In particular, the idea of conceptual ecology was criticised because it focuses solely on the learner's cognition and not on the learner as a whole.

Furthermore, it does not consider other participants (i.e., the teacher and other learners) in the learning environment and how these participants influence the learner's conceptual ecology, thus influencing conceptual change. Strike and Posner (1992) also recognized similar shortcomings in their original conceptual change theory and proposed that affective and social issues affect conceptual change.

Social constructivist and cognitive apprenticeship perspectives have also influenced conceptual change theory (Hewson, Beeth, & Thorley, 1998). These views on learning encourage discussion among learners and the teacher as a means of promoting conceptual change. Thus, conceptual change is no longer viewed as being influenced solely by cognitive factors. Affective, social, and contextual factors also contribute to conceptual change. All of these factors must be considered in teaching or designing learning environments that nurture conceptual change (Duit, 1999).

As mentioned above, learner preconceptions are resistant to change. Because learners have banked on these existing notions to understand and function in their world, they may not easily discard their ideas and adopt a new way of thinking. Therefore, simply presenting a new concept or telling the learners that their views are imprecise will not result in conceptual change. Teaching for conceptual change necessitates a constructivist approach in which learners take an active role in restructuring their knowledge.

Cognitive conflict strategies, derived from a Piagetian constructivist view of learning, are operational instruments in teaching for conceptual change (Duit, 1999). These strategies encompass designing circumstances where learners' existing conceptions about particular phenomena or topics are made explicit and then openly challenged in order to create a state of cognitive conflict or disequilibrium. Cognitive conflict strategies are brought into line with Posner et al.'s theory of conceptual change in that their common goal is to craft the four conditions necessary for conceptual change. This implies that learners must become dissatisfied with their current conceptions and accept an alternative conception as intelligible, plausible, and fruitful.

In the Conceptual Change Instructional Model, cognitive conflict can be used as the basis for developing a number of models and strategies for teaching for conceptual change. Among these are the Generative Learning Model (Cosgrove & Osborne, 1985), the Ideational Confrontation Model (Champagne, Gunstone, & Klopfer, 1985), and a teaching strategy using strange data (Chinn & Brewer, 1993). Although these models suggest different methods and techniques, they share a structure similar to the conceptual change teaching strategy proposed by Nussbaum and Novick (1982):
Reveal student preconceptions
Discuss and evaluate preconceptions
Create conceptual conflict with those preconceptions
Encourage and guide conceptual restructuring
Reveal Student Preconceptions

A simple assumption in teaching for conceptual change is "the key constructivist idea that construction of new conceptions (learning) is possible only on the basis of already existing conceptions" (Duit, 1999, p. 275). Although existing knowledge allows us to interact with the world, we are not necessarily conscious of it. Thus, the first and most significant step in teaching for conceptual change is to make learners aware of their own ideas about the topic or phenomenon under study.

Learners' conceptions can be provoked by ensuring that instruction begins with an exposing event. The exposing event is any situation that requires learners to use their existing conceptions to interpret that event. Exposing events may be of two types: a situation for which the outcome is not known or one in which the outcome is known (Chinn & Brewer, 1993). In the "unknown" case, the teacher asks learners to predict the outcome and explain the basis for their prediction. In the "known" case, learners make no predictions; however, they must furnish an explanation of the event.

Learners can utilise a variety of ways to represent their ideas. The options can be writing descriptions, drawing illustrations, creating physical models, drawing concept maps, designing web pages, or creating any combination of these as evidence of their understanding of a particular concept. If computers and the appropriate software

are available, students can develop presentations using PowerPoint, create models or simulations, or construct concept maps. Irrespective of the method, the goal of this step is to help learners distinguish and begin to refine their own ideas and understandings. Once the learners' conceptions are made explicit, teachers can use them as the basis for further instruction.

The aim of this step is to have learners shed light on and revise their original conceptions through group and whole-class discussions. The teacher should lead the class in evaluating each conception presented for its intelligibility, plausibility, and fruitfulness in explaining the exposing event. Nussbaum and Novick (1982) suggest that the teacher should accept all the representations and abstain from value judgments. The teacher should also refer to the representations by learner name.

After the whole-class discussion, learners with differing conceptions work in pairs or groups to evaluate each other's ideas. Each group selects one conception or a different conception modified through evaluation, provides a rationale for the selection, and presents that rationale to the whole class. Learner motivation can be augmented by allowing the learners to vote for the conception that they think explicitly explains the exposing event.

The more learners become aware of their own conceptions through presentation to others and by evaluation of those of their peers, the more they become dissatisfied with their own ideas and conceptual conflict begins to build. By spotting and accepting the inadequacy of their conceptions, learners become more open to changing them.

A greater conflict can be generated when the teacher creates a discrepant event. The discrepant event is a phenomenon or situation that cannot be explained by the learners' current conceptions but can be explained by the concept that is the topic of instruction. At this point, if no learner has offered the "correct" conception at that particular moment, then the teacher may suggest it as one given by a student in a previous class.

If the teacher does not know the range of learner alternative conception about a topic or phenomenon before the conceptual change activities begin, it may not be possible to plan a discrepant event in advance. In such cases, the teacher should ask the learners to suggest a test or method to determine which of the learners' conceptions best explains the "exposing event." In cases where the subject is Science, the learners may suggest some type of experiment. The teacher could also create a discrepant event by presenting anomalous data evidence that contradicts the learners' current conceptions (Chinn & Brewer, 1993).

Students should be given time to reflect on and reconcile differences between their conceptions and the target theory. The teacher should combine reflective activities into lessons to promote cognitive accommodation or restructuring of the learner preconceptions. A cooperative learning environment is necessary for successful conceptual change instruction. There must be opportunities for discussion; learners must feel safe in sharing their viewpoints as they consider and evaluate other perspectives (Bruning, Schraw, & Ronning, 1999; Scott, Asoko, & Driver, 1991). The "safety factor" is especially important where teaching employs the cognitive conflict strategy presented above. One research study (Dreyfus, A., Jungwirth, E., & Eliovitch, R., 1990) found that low achieving learners experienced a loss of self-confidence and viewing conflict as another failure.

For successful implementation of the conceptual change instructional strategy, the teacher and the learners should have some experience with constructivist learning and cooperative learning groups. Learners who are familiar with a transmission style of teaching (i.e., direct instruction) may be less motivated to participate in discussion-based activities (Scott, Asoko, & Driver, 1991). The teacher must be skilful in managing class groups and be able to take up a facilitative role.

Teaching for conceptual change is not an easy process; it is more time-consuming than traditional, rote teaching methods. It requires a supportive classroom environment in which learners feel confident in expressing and discussing their ideas. Conceptual change instruction also requires that the teacher possesses well-developed facilitation skills and a thorough understanding of the topic or phenomenon in question. Conceptual change learning results in better conceptual understanding by the learners. Consistent evaluation and clarification of conceptions helps students develop meta-conceptual awareness; that is, they come to understand how they develop their beliefs (Vosniadou, 1994).

Even if a specific instructional approach has been presented here, other constructivist teaching approaches may also promote conceptual change learning. The unique features of conceptual change instruction are that learners make their conceptions explicit so that they become aware of their own ideas and thinking, and that learners are constantly engaged in evaluating and revising their conceptions. The goal of teaching for conceptual change is for learners to adopt more fruitful conceptions while discarding the alternative conceptions they bring to the classroom. Learners are more likely to rid themselves of conceptions that they have evaluated than those that they have not examined at all.

A variety of computer tools and Web-based instructional materials can be used in teaching for conceptual change. These tools are used to create concept maps. A concept map is a diagram consisting of boxes or graphics that represent concepts and labelled lines that represent relationships between the concepts. Learners can create concept maps to present their conceptions about a particular topic at the beginning and throughout the teaching period. Concept maps allow learners and the instructor to see how their conceptions change over time. Two recommended concept mapping tools are Inspiration and IHMC Concept Mapping Software or C-Map. Concept maps created in C-Map can be shared across a network. C-Map is a free download, and Inspiration can be downloaded for a free 30-day trial. Sample concept maps and background information about concept mapping are available at the C-Map web site.

Computer simulations are used to support conceptual change. The use of appropriate interactive visualization simulated software available for teaching concepts of Physics in the classroom has become important to overcome the limitations of real experiments and helps students to construct their knowledge through less guided exploration. In addition, computer simulations are used to provide discrepant events in conceptual learning because they have the capacity to provide learners with an exploratory learning environment (Zacharia & Anderson, 2003).

Computer simulations can also motivate and actively engage learners towards construction of their knowledge. For example, the research of the Physics Education Technology (PhET) project (Wieman et al., 2008a) particularly related to simulation and students' motivation has developed more than 60 interactive simulations on the topics of Physics. These simulations are freely available on the website (http:// phet.colorado.edu) and can be easily run online or may be downloaded to a local computer or installed to a CD (Wieman et al., 2008b). This has the advantage that learners can freely experience, explore, and manipulate the micro-world by changing the parameters and visualizing immediately the consequences of their actions (Papert, 1980; Bliss & Ogborn, 1989). In this way, learners can interpret and reflect on the domain of knowledge represented by the micro-world, formulate and test hypotheses, and reconcile any conceptual conflict between their ideas and observations in the micro-world. All these require learners to reflect on and make explicit their conceptions and this is conducive to conceptual change.

Computer simulations have been shown to be effective in fostering conceptual change in several studies (e.g., Zietsman & Hewson, 1986; White & Horwitz, 1988; McDermott, 1990; Gorsky & Finegold, 1992). In particular, Zietsman and Hewson (1986) used a computer simulation to diagnose and remediate alternative conceptions of velocity. Their results show that computer simulations can be credible representations of reality and that remediation produced a significant conceptual change in learners holding the alternative conception.

Computer simulations also provide learners with highly focused objects for reflection and discussion. Working in small groups, students can discuss and argue about their ideas and negotiate meaning. When confronted with discrepant results, they have to reflect on their ideas, discuss and try new approaches, and rerun the program. Larners' conversational interactions while working together on the program can provide valuable data for eliciting their conceptual development (Krajcik, Simmons, & Lunnetta, 1988).

Moreover, if in groups learners are given a chance to run the simulations, then the simulations can offer them opportunities to actively interact in their learning at reasonable scale and time frame. In short, the simulations are designed to be interactive, engaging, and also to make explicit certain visual representations (Wieman et al., 2008b). Rutten et al. (2012) reviewed 51 articles between 2001 and 2010 and found that simulations are useful for visualisation and reported large effect sizes of well-designed simulation-based instruction. Therefore, because of the complex and invisible mechanical energy related concepts, interactive Physics computer simulations of selected conceptual areas of the concepts are used as part of the supportive learning strategies.

The conceptual change teaching strategy that will be employed in this study will consider the multi-dimensional perspective as given in figure 3 below:

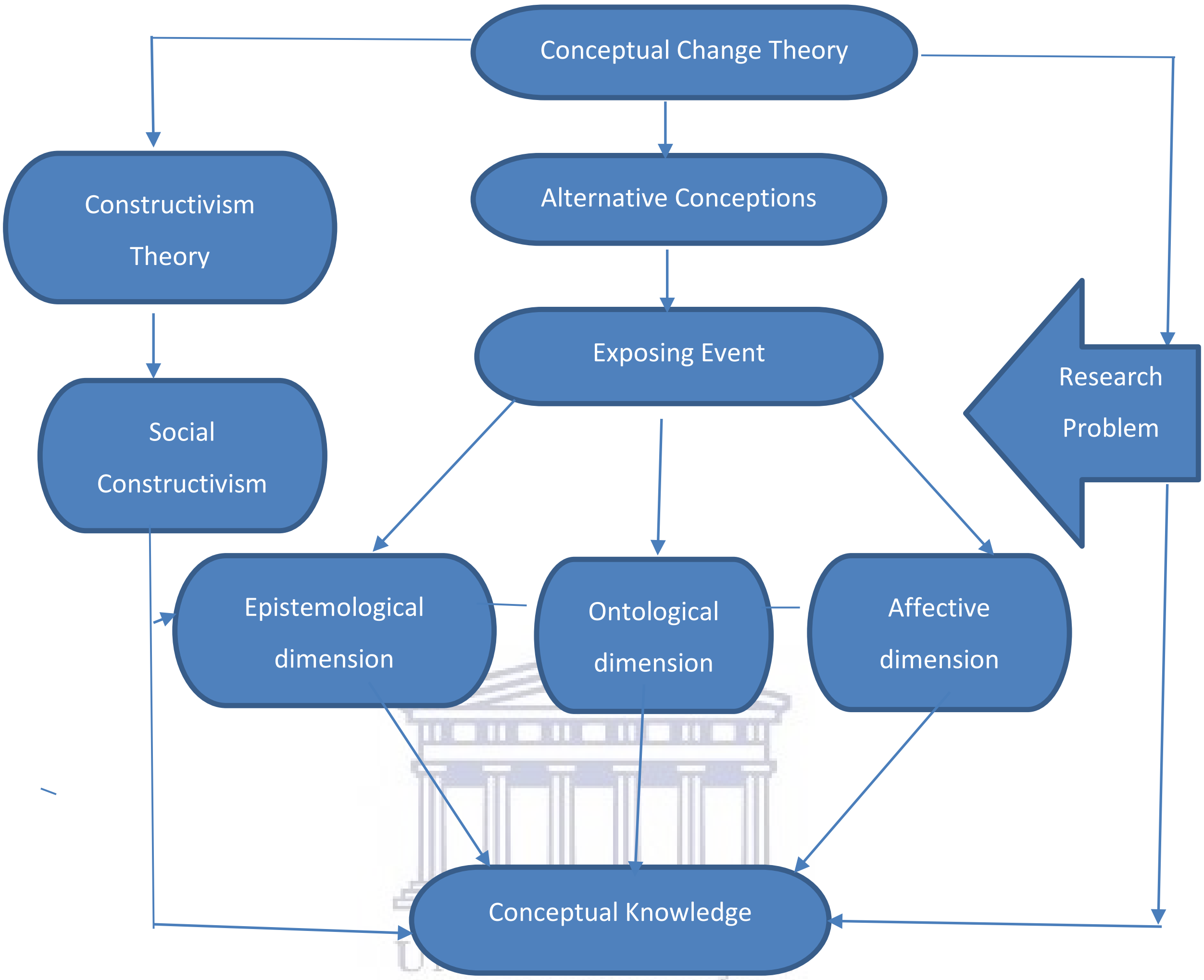


Figure 3: The multi-dimensional perspective of the conceptual change process

2.3 Teaching about energy

Warren (1982) maintains that Energy is an abstract Mathematical concept, and argues that teaching must start from its scientific definition or else all that is taught is in disarray and largely meaningless. The Nobel Prize winning physicist, Richard Feynman, begins his discussion of the scientific idea of Energy as follows:

There is a fact, or if you wish a law, governing all natural phenomena that are known to date. There is no exception to this law – it is exact so far as is known. The law is called the Conservation of Energy. It says that there is a certain quantity, which we call Energy that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a Mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, and find it is the same (Feynman, 1963).

A vast number of messages is noted here. First, the most important notion about Energy is that it is conserved. In every event and process; there is the same total amount at the end as there was at the beginning. This makes Energy a useful quantity. It is not too strong to say that if Energy was not conserved, it would not exist as a scientific concept. Second, Feynman also emphasises that Energy is an abstract, Mathematical idea. It is a property of an object or system, which can be given a numerical value. It is not concrete 'stuff'. That means that we should talk about the energy of an object or system, but not about the energy in, or contained in, or stored in it.

Finally, Feynman points out that Energy is not a mechanism that explains how things happen. It does not help us to understand how or why they happen. When we introduce pupils to Energy ideas, we are not providing them with an idea which is of immediate practical use. Instead we are introducing them to a very general, overarching point of view that can be used to think about an enormously wide range of phenomena, across all the sciences. Energy provides an integrating framework. It can be intellectually satisfying to see diverse events from a single unifying perspective. It is a 'neat idea', rather than a practically useful one. Later, of course, it can become very useful, for anyone who pursues science further. But it only really comes into its own when we can treat the ideas mathematically, and calculate amounts of energy in different situations.

Feynman describes energy as 'a numerical quantity, which does not change when something happens'. But he does not attempt to say what this numerical quantity measures. As several numerical quantities do not change when an event occurs (for example, the total mass, the total electric charge, the total momentum, and some others), it is necessary to say something, however imperfect, about what the numerical quantity we call 'energy' measures. Energy is a measure of the amount of work an object or system is capable of doing, under ideal conditions. 'Work' is, itself, a precisely defined scientific term (the product of a force and the distance moved along its line of action). But even if we think of 'work' in a looser, everyday sense, this definition of Energy makes sense: when we have a lot of energy, we feel capable of doing lots of work; when we have little energy, we are incapable of doing much work. Energy is a measure of the capacity of an object or system to do work.

For Warren (1982), the major flaw in a qualitative treatment of energy is that it makes energy appear to be a 'magic substance', invisible and intangible, but able to flow from place to place, changing its form as it goes, whilst staying constant in quantity. Others, however, see this as an acceptable, indeed a valuable, way of simplifying a difficult idea (Duit, 1987). When we use a model of energy as something that can be stored in different places (and ways) and can flow from place to place, it is tempting then to label the different 'forms' that energy can take.

This 'forms of energy' approach has, however, been the subject of much debate. One criticism is that pupils just learn a set of labels, which adds little to their understanding. The forms of Energy approach can also lead to analyses of situations which introduce unnecessary variables that do not contribute to understanding. Consider the simple situation of an object falling from a height or sliding down a smooth slope. Here we are interested in the energy of the same object at the beginning and end – and it seems clearer to talk about its potential energy having been transformed (or converted) into Kinetic Energy than to try to explain it using only the word 'transfer'.

Ogborn (1986), however, points out that it is incorrect to say that 'Energy is what makes things happen', or that something happens because of energy. So statements like the following are incorrect:

A ball keeps moving because it has kinetic energy.

Petrol makes a car go because petrol has energy.

A stone falls because it has potential energy.

One reason for avoiding causal statements like these is that energy is not a mechanism. We need to use other ideas (like force) to explain how and why things happen. Looking at an event from an energy point of view might throw light on some aspects of it but does not help to explain how or why it happens. A second reason is that energy is conserved. So it cannot explain why the process runs in one direction rather than the reverse (which would also conserve energy).

A good place to begin the teaching of energy ideas is with energy resources, (including food). There are ideas about energy resources and the way we use them that are important for all citizens and which all young people should be taught. The next stage is to help learners begin to think about events and processes in energy terms. Here again, we will use a model of energy as a quasi-material substance that can be stored in different places (and in different ways) and can be transferred from one object or system to another. However, it is important to take some care about exactly how you do this, and the terms you introduce and use. In the approach suggested below, energy ideas are introduced qualitatively, but in a way that leads easily to a more quantitative understanding at a later stage.

As Feynman highlights in the passage quoted in section above, the most important fact about energy is that it is conserved. The conservation of energy is one of the fundamental principles of science. So in talking about processes and events in energy terms, we do not only want to describe where the energy is stored and how it is transferred. We also want to tell pupils that, in any event of process, the amount of energy lost by the store is equal to the sum of the amounts of energy gained by the various reservoirs. Energy is a kind of book-keeping quantity. The ‘energy books’ must balance at the beginning and the end. It should always tally.

2.4 Review on international and national Physics Education

Conceptual change is based on cognitive conflict and the resolution of conflicting perspectives. It is also based on building on the learner’s existing ideas and extension thereof. Conceptual change ensures that learners play an active role in restructuring their knowledge. Furthermore, the design of appropriate interventions by teachers provides scaffolding for the new way of thinking.

Şahin & Çepni (2010) introduces the concept cartoon, animation and diagnostic branched tree as the teaching materials that can support conceptual change texts related to gas pressure in Grade 8. As the conceptual change texts activate the learners’ prior knowledge, concept cartoons will be used to diagnose alternative conceptions. Animation could be used to concretise abstract concepts. The diagnostic branched tree could be used as the springboard for discussion in the classroom that will effect conceptual change. It is the responsibility of the teacher to create an environment conducive for classroom discussion so that learners can understand scientific knowledge.

According to (reference) this was a great conference presentation that enlightened many researchers as far as the learner-teacher support materials for conceptual change are concerned. Conceptual change can now be tackled from this perspective. This is a challenge to Physics teachers with a curriculum that puts the learner at the centre of the learning process.

Igwebuike (2012) sought to find out if higher achievers in integrated Science taught using the conceptual change pedagogy will achieve significantly better than their counterparts taught using the expository strategy. An experimental group was taught using the conceptual change pedagogy while a second group was taught using the expository method. The students in the experimental and control groups were found to have initial differences in cognitive and affective achievements from the analysis of the pre-tests [$t_{(98)} = 4.93$, $p<0.05$] and [$t_{(98)} = 9.72$, $p<0.05$] respectively. The corresponding multiple classification analysis reveals that high achievers exposed to conceptual change pedagogy had an adjusted cognitive achievement mean score of 17.28 while their counterparts taught by using expository method had an adjusted cognitive achievement mean score of 17.40

With respect to affective achievement, there was significant difference in favour of high achievers in the experimental group [$F_{(1,97)}= 27.942$, $p<0.05$] (Table 5). This group had an adjusted post-test affective achievement mean score of 62.84 while their counter parts taught through expository method recorded an adjusted post-test mean score of 58.54. No statistically significant difference was found between the two groups. However, a significant difference was found in affective achievement between the two groups.

All the parts of the research link well. What is said in the introduction of the study is what one comes across throughout the study. I applaud the use of three research instruments for triangulation. Moreover, the instruments are piloted before the actual research. The instructional treatment is explained in great detail. There is a link between the school curriculum and the items in the tests and between the school curriculum and the items in the interview schedule. However, the details of when and how the conditions of conceptual change are implemented have not been reported on.

Nwankwo & Madu (2012) examines the effects of the analogy teaching approach on the conceptual understanding of the concepts of refraction of light in Physics. Data was collected from 111 Physics learners of Nigeria using the pre-test and the post-test. The results showed that the usage of analogy teaching model had a positive effect on learners. The analysis of data shows that students performed better with a mean of 31.74 and S.D. of 8.49 when taught the concept of Refraction using analogy teaching model than when taught the same concept using the conventional lecture method with a mean of 27.13 and a S.D. of 9.03. Hence, the use of analogy in teaching was able to bring about a significant change in concept acquisition in these students.

The results also show that the female students attained conceptual change in SS 2 Physics with a mean of 34.09 and a standard deviation of 6.43 better than the males with a mean of 25.29 and a standard deviation of 9.08. That is, the females performed better than the males when taught the concept of Refraction of light irrespective of the method used. The researcher recommends that Physics teachers and all stakeholders in education should endeavour to incorporate analogy instructional model as one of the approaches to be adopted in Nigerian Secondary schools.

Kaboro et al (2015) report on the effect of using a dance analogy derived from learners' socio-cultural environment and deals with students' conceptualisation of heat concepts in Secondary School Physics. The results were compared with those of teaching using the conventional methods. Results showed that teaching the traditional dance analogy led to higher conceptual gains of Physical Heat concepts compared to teaching using conventional methods. It was recommended that teachers should often consider students' socio-cultural knowledge as the basis of selecting and designing analogies to facilitate conceptual change in teaching abstract Science concepts.

On the positive note, the researchers made it clear that what is learnt during instruction depends on learners' prior ideas, the cognitive strategies they have available and their own particular interests and purposes. In addition, their work is logically structured and the topic has been covered adequately. It reads well and is not confusing. Again, the authors are not controversial. Other writers in the field are engaged as well as in "The results of this research suggest that there is a general trend in the way conceptions are constructed and modified (Calik, Ayas and Coll

2009; Dikkers and Thijs, 1998; Orgill and Bodner, 2004)". Most of all, researchers have used an analogy from all the learners' socio-cultural environment, the traditional dance of Kenya.

Zeynel (2015) investigated the effect of enriched 5Es model of grade 7 learners' conceptual change levels about electric current. Within the enriched 5Es model animation, simulations, refutational text and worksheet were employed. A conceptual questionnaire with twelve items was use to collect data. The results indicated that the experimental group out-performed in conceptual understanding as compared to the control group. Given the results of the enriched 5Es model in remedying the related alternative conceptions, it is recommended that it should be deployed to teach the other abstract Science concepts.

A good lesson learnt from this piece of work is that it is important to look for a gap from previous related literature where new research can fit in. The gap was on the use of different teaching and learning activities within the enriched 5Es model to facilitate conceptual change of electric current concepts.

Gyoungho & Taejin's (2011) study focussed on the relationship between cognitive conflict and responses to anomalous data when learners are confronted with a counter-intuitive demonstration in the form of a discrepant event. Cognitive conflict introduces the first step in the process of conceptual change.

On the other hand, Zhon (2012) argues that the outcome of the classroom discourse cannot be oriented to be the replacement of the learners' intuitive conceptions, rather co-existence between scientific understanding and culture based views is considered to be a reasonable and realistic goal.

Özkan (2012) presents studies that have proven the effectiveness of the conceptual change strategies in recovering learners' misconceptions. These studies also explain all the details of conceptual change.

Özkan & Şelcuk (2013) presents examples of the conceptual change texts that Physics teachers will benefit from in the teaching and learning of Sound in Physics. The conceptual change texts on Sound have not been found in any current literature and this gesture is appreciated. The authors advise that the texts can be used in crowded classrooms.

McGregor (2014) reports on the conceptual change theory that can contribute to a deeper understanding of concepts if there is transdisciplinarity. The learner must understand the concepts related to the Physics topic and other disciplines, and then the learner will be able to solve complex concepts. That learner knows how to learn through the inquiry-based approach, learn to do through project based learning, learn to live with others through collaboration on a local and global scale, and learn to discover oneself. The learner with the 21st century skills will be able to understand complex problems in life.

Forthcoming is the South African context and Dega (2012) investigates the effect of conceptual change through cognitive perturbation using Physics interactive simulations in Electricity and Magnetism. The categorization of students' conceptions was based on the epistemological and ontological descriptions of these concepts. In qualitative results, six categories of alternative conceptions were identified. They are naïve Physics, lateral alternative conceptions, ontological alternative conceptions, mixed conceptions and loose ideas. It was concluded that there is a statistically significant difference between cognitive perturbation using physics interactive simulations (CPS) and cognitive conflict using Physics interactive simulations (CCS) in changing students' alternative conceptions. It was suggested that in conceptual areas of Electricity and Magnetism, cognitive perturbation through interactive simulations is more effective than cognitive conflict through interactive simulations in facilitating conceptual change and thus, should guide classroom instruction in the area.

Dega's report flows logically from the introduction to the conclusion and each and every term or process that makes this piece of work understandable is explained in great detail. What the author introduced at the beginning of every chapter is reported on explicitly. The context of the study links well with all the parts of the report. The collection of data, its analysis and the results addressed the research questions. The research questions are used well in guiding the research methodology to the conclusion of the study.

Of all the articles reviewed on the conceptual change approach, Dega is the first researcher that has dug deep into the evolutionary process of conceptual change than the revolutionary process and the results were positive. The researcher had unequivocally stated that revolutionary processes of conceptual change had shortcomings and many studies attest to that. Secondly, the author gives a detailed account of research instruments to be used prior, during and after the intervention; and how the intervention will be conducted so as to slowly and gradually assist the learners in understanding the scientific knowledge better. The recommendations towards the end of the study are an eye opener to other researchers. The researcher recommends that researchers should undertake an inclusive, multi-perspective conceptual change research because conceptual change is a complex process.

Rankhumise & Sitwale (2014) reports on the findings of the study that investigated the effect of a bicycle analogy in alleviating alternative conceptions and other conceptual difficulties about electric circuits. The research methodology is not clearly stated. Only one research instrument was used for the pre- and post-tests, a test and as such this instrument is unreliable because it was not triangulated. The learning strategy perspective supporting the analogy using conceptual change was not stated. Even the learning events that triggered conceptual change were not explained under the intervention stage. However, data analysis showed a normalised gain score of 0, 4 between the pre and post-tests. The mean scores for the pre- and post-tests were32,4 and 61,6 respectively. The results signified that the instructional intervention, involving the use of the bicycle analogy had been effective in significantly alleviating the alternative conceptions and other conceptual difficulties about electric circuits held by the participants.

Kapartzianis (2014) investigates the vocational students' conceptual understanding of electricity by proposing a multi-dimensional and pragmatic approach to conceptual change. Unlike the previous researcher, the mixed methods employed are clearly stated. The research instruments for collecting data are the test, the interview schedule and the field notes to triangulate data collected. The pre- and post-test scores were 34,87 and 62,52 respectively. Test scores indicated that there was a statistically significant difference of between the students' pre- and post-test scores. The majority of students during post pre-test interviews justified their answers incorrectly, but more than 80% answered correctly in the post post-test interview. Qualitatively, the interviews and field notes were analysed.

In summary, a review of the related literature indicates that alternative conceptions are one of the factors that lead learners to failure in the learning of Physics. To teach Physics effectively, alternative conceptions must be spotted and overcome through the usage of an effective teaching approach. The conceptual change approach impacts positively on the teaching and learning of Physics at all levels. Studies reviewed above suggest that epistemological, ontological and affective perspectives (multiple perspectives) of the conceptual change model should be employed in order for the conceptual change model to be more effective because the cognitive conflict in the classical conceptual change model could have limitations to provide appropriate conceptual anchors to bridge the gap between the students' alternative conceptions and scientific conceptions. In addition, the learning of Science is complex and idiosyncratic. These findings have a significant bearing on my research, which focuses on teaching for conceptual change at the Secondary level. The next section presents the teaching of the Principle of Conservation of Mechanical Energy using the conceptual change approach.

2.5 Research on the Principle of Conservation of Mechanical Energy internationally and nationally

In Thailand, Pitchimal et al. (2014) posits that the purpose of this research was to study scientific concepts of the student in conservation of mechanical energy both before and after learning through Predict-Observe-Explain (POE) approach. The POE teaching strategy is based on the constructivist learning theory. The target group was 34 Grade 10 students of Strisuksa School, The Office of Secondary Education District Area 27, Roi-Et, those studied in the second semester, academic year 2014. The students' scientific concepts in conservation of energy had been studied by using pre-test and the results were used as guiding to develop the conservation of mechanical energy lesson plans. The post-test was done soon after the POE was finished. The evaluation tools consisted of scientific conceptual test, multiple choices combined with short explanations for chosen options. The test items were based on the following conceptual areas: definition of Mechanical Energy; Principle of Conservation of Mechanical Energy; and application of the Principle of Conservation of Mechanical Energy. The conceptual test was used to diagnose learners' misconceptions and also as a guide in the development of the lesson plan to be used in the intervention program. The post-test, also a scientific conceptual test similar to the pre-test was administered to test for improvement in learner conceptual understanding of scientific concepts related to the Conservation of Mechanical Energy.

The collected data were analysed comparing the difference between pre-test and post-test scores. It was statistically analysed using the t-test. The learners' scientific concepts in the pre- and post-tests were analysed under the five categories: complete understanding; partial understanding; partial understanding with specific misconceptions; alternative conceptions; and no understanding. The findings revealed that students' scientific concepts in prior learning could be interpreted into various categories and the majority of them diverged from scientific concepts, but the post-test performance of learners showed that scientific concepts converged to the scientific concepts. The results showed that the scores about conceptual understanding of Conservation of Mechanical Energy was significantly higher in the post-test than in the pre-test ($t = 12{,}333$; $df = 33$; $p = 0{,}05$). It could be concluded that the POE approach supported the learners to gain their understanding of conservation of energy.

The study is in line with the 21st century teaching and learning strategies because the POE learning strategy allows the learner to be actively involved during the learning process. The Physics curriculum internationally is now learner-centred and the acquired scientific knowledge is applied in everyday life. However, the results of the study may not be reliable as the study is based on one research instrument only, the conceptual test.

In South Africa, Rankhumise et al., (2014) investigated the learners' alternative conceptions relating to the Principle of Conservation of Mechanical Energy. The study investigates the effectiveness of an inquiry teaching and learning sequence aimed to remedy alternative conceptions that learners have relating to mechanical energy and the conservation thereof. The teaching-learning sequence follows the design principles of progression and integration in the implementation of the OBE curriculum.

The research sample consisted of thirty-seven learners enrolled at a South African high school situated in a rural village, in the Northern Province. An action research methodology was employed. The research method is divided into three stages namely action planning, action taking and the evaluating stage. In action planning, a pre-test questionnaire consisting of six items was administered to diagnose the alternative conceptions held by learners.

In the action taking (intervention) stage inquiry orientated six lessons of forty-five minutes each were presented to learners to remedy alternative conceptions held or to build on already existing knowledge. Lessons were designed such that they enable the learners to distinguish the energy forms; energy types in a system; energy transformation concept; the Principle of Conservation of Mechanical Energy; and the application of energy transformation and the Principle of Conservation of Mechanical Energy in other contexts. Learners also carried out a research project in groups of six. The same questionnaire that served as the pre-test was again used in the post-test. The questionnaire content was moderated for validity. To ensure reliability, the same questionnaire was administered to the same target group a month later and the same results were obtained.

Data analysis was carried out by the use of the average normalised gains. The statistical data of the pre- and post-tests were compared, analysed and interpreted. The normalised learning gains of 80% were calculated from the results to determine the achievements of the inquiry-based learning sequence. The effectiveness of the intervention was indicated by the amount of conceptual change accomplished that followed from a calculation of the normalised learning gain.

Pitchimal et al., (2014) and Rankhumise et al, (2014) both conducted research on the investigation of the effect of the use of the teaching strategies that can promote conceptual change in the teaching of the Principle of Conservation of Mechanical Energy. Pitchimal et al. used the Predict-Observe-Explain (POE) teaching strategy whereas Rankhumise et al. used the inquiry-based teaching strategy. Both authors used the pre- and the post-tests as the research instrument for collecting data although one is in the form of a questionnaire while the other is in the form of multiple-choice questions. The data of both studies were statistically analysed. The results signified that teaching strategies used in the instructional intervention were effective in reducing learners' alternative conceptions of Mechanical Energy.

There is a gap in both studies where a further research can fit in. Both studies view conceptual change from the epistemological and ontological points of view because in the individual intervention programs concepts being investigated are described and their nature viewed. The affective view was not considered nor implemented. A good teacher teaches but a great teacher inspires. Creating an environment that supports learning motivates learners to learn. Secondly, integrating technology into teaching and learning, the 21st century skill in the form of computer simulations has not been used so far as a learning tool that can support conceptual change in the teaching of the abstract concept, the Principle of Conservation of Mechanical Energy.

Computer simulations arouse interest in learners. Computer simulations have been shown to be effective in fostering conceptual change in several studies (e.g., Zietsman & Hewson, 1986; White & Horwitz, 1988; McDermott, 1990; Gorsky & Finegold, 1992). Learning using simulations will help the learners learn consciously and at their own pace because a learner has the opportunity to repeat a learning event over and over again in trying to understand the concept, failing which the learner can also ask from group members or the teacher. Learning becomes meaningful because it is a gradual process that is not forced at that instant.

2.6 Conclusion

This chapter firstly explored the theoretical framework underpinning the study where constructivism and the conceptual change theory are explained. Secondly, literature on teaching about Energy is explored. The chapter also examined international and national Physics Education on the effect of the conceptual change strategy. Finally, studies on the teaching of the Principle of Conservation of Mechanical Energy is explored

The following chapter will explain the research design, data collection, and data analysis methodology employed in the study.

CHAPTER 3
METHODOLOGY

3.1 Introduction

The purpose of this chapter is to give a detailed account of the research design. This chapter outlines the methodology to be employed to collect the research data and the justification for the choice of research methods employed. The study is directed to addressing the following main research question: How can the teaching and learning of the Principle of Conservation of Mechanical Energy through conceptual change improve learner performance?

The chapter first describes the research methodology in terms of its approach, design, context, participants and methods that were used to collect, analyse and verify the data that were envisaged to assist the researcher in answering the research question above. Finally, the chapter concludes with the ethical considerations that the researcher endeavours to uphold while conducting this study.

3.2 Research Approach

This study adopted a single case-study design. The study itself is a case of a formal school setting where a class of thirty, Grade10 Physical Sciences learners participated in the study. A case study does not rely on any particular method of data collection; any method of data collection can be employed (Merriam, 1988; Yin, 2007).

Studies (Stavy, 1998; Vosniadou, 2007) have shown that the nature of the study of conceptual change is a very complex and gradual on-going learning process. This is mainly because of the fact that learners' conceptions waver from one context to another, and unique features found in learners' conceptual change are diversified (Li et al., 2006). This study followed a mixed method approach, including both qualitative and quantitative research methods. Using such an approach affords the researcher an opportunity to utilise what is best from both qualitative and quantitative approaches (Creswell, 2003). The rationale for this mixed-methods design was to use the quantitative data to elucidate the qualitative findings and also to follow up on leading and second rated cases (McMillan & Schumacher, 2010:401).

Mixed methods are used in triangulation, since every approach has its strengths and weaknesses, and a combination of both qualitative and quantitative approaches increase validity (Babbie & Mouton, 2001). For the quantitated fragment of the study, a pre-test and a concept map design (Creswell, 2009:158) were used to determine the effectiveness of the intervention teaching strategy. Qualitative data collected by means of video-recordings during the intervention was used to illuminate the quantitative findings.

Green, Caracelli, Valerie and Graham (1989) identified the following five advantages of using mixed methods. research process

- Triangulation: Tests the consistency of the findings obtained through different instruments. This study made use of data collected from the tests, concept maps and interview to maintain consistency of findings.
- Complementarity clarifies results from one method with the use of another. In this study, focus group interviews qualified scores on the pre-test and concept maps.
- Development: Results from one method shape subsequent methods or steps in the. In this study, the pre-test provided the teacher with necessary information regarding the alternative conceptions on the principle of conservation of mechanical energy that learners were bringing to the classroom so that the teacher can prepare the intervention lessons that will specifically target those alternative conceptions. After the intervention lessons, the concept map was used to assess the effectiveness of the conceptual change approach in helping the learners to voluntarily and consciously disown alternative conceptions after new experiences and intensive discussions in the classroom and accept the scientific ones. The drafting of an interview schedule gave a deeper insight as far as the effect of the conceptual change approach in the teaching of the Principle of Conservation of Mechanical Energy is concerned.
- Initiation: Stimulates new research questions or challenges from results obtained through one method.
- Expansion: Provides richness and detail to the study, exploring specific features of each method.

3.3 Research Design

A research design is generally described as a strategic framework for action that serves as a bridge between research questions and the implementation of the research (Durrheim, 2006). In other words, it is a logical plan that ensures that evidence obtained enables the researcher to answer the research questions. Durrheim (2006) identified the four dimensions for research designs as: the purpose of the study, the theoretical paradigm that informs the study, the context in which the study is conducted and the research techniques used to collect and analyse data.

A pilot study was included in the research design prior to data collection, to determine the feasibility of the pre-test and interview schedule in terms of the relevance of the questions and applicability of the content. This utilisation of pilot studies is in line with Huysamen (cited in Strydom, 2000), who posits that the aim of pilot studies is to investigate the suitability and feasibility of the research instruments.

The guidelines followed in the design of the study were:

3.3.1 Area of Study

The study was conducted in a Senior Secondary School. The school is situated in the rural district of the Intsika Yethu Municipality in the Northern Region of the Eastern Cape. The school serves Grade 10 to 12 learners from the Intsika Yethu Municipality community and beyond. About 70% of the learners in each Grade do Physical Sciences as a subject. The study targeted Grade 10 Physical Sciences learners that had been taught the Principle of Conservation of Mechanical Energy already using a different teaching approach from the one used by the researcher in the study.

3.3.2 Population

There are 115 Physical Sciences learners in Grade 10 in the school under study. They were grouped into three Grade 10 classes doing Physical Sciences. Learners in two of the three classrooms are taught by one teacher and learners in the third classroom are taught by the researcher.

3.3.3 Sampling technique

The study focussed on one of the three classes with thirty Grade10 Physical Sciences learners of mixed gender. This particular class of thirty learners was purposely `selected because it is the class that had not been taught by the researcher. In addition, the intention of the researcher was to specifically reteach a topic that had already been taught by another teacher using a conceptual change approach. The thirty learners wrote the pre-test, took part in the intervention programme and thereafter drew concept maps. Later, focus group interviews were conducted using the same thirty learners but were then divided into five groups of six learners each. Sampling is summarised in the Table 3 below:

Table 3: The sampling technique

Participants	Sample Size	Selection Technique	Criteria
30 learners from one class that will be taught and tested	30	Purposive	Grade 10 Physical Sciences learners that were not taught by the researcher. The school programme should not be disturbed.
30 learners to undergo semi-structured interviews	5 groups of 6 learners each (focus groups)	Whole population of thirty	

3.3.3.1 Purposive Sampling Method

Teddlie and Tashakkori (2009) provide certain characteristics of purposive sampling which firstly addresses specific purposes related to research questions; secondly, is selected because it uses the expert judgement of researchers and experts, its procedures focus thirdly on the depth of information that can be generated by individual cases, and lastly because the samples used are typically small (30 or fewer cases). Purposive sampling was used in the study to select the thirty Grade 10 participants making up a Physical Sciences class. The purpose of selecting this particular class was to check if the conceptual change approach used to teach the same learners that had been taught the same topic before using a different teaching approach had a positive effect on their understanding of scientific concepts.

3.4 Data Collection Plan

The data collection process was designed based on the research sub-questions that follow and those steps are identified in Table 4.

(i) What are learners' initial understanding of the Principle of Conservation of Mechanical Energy concepts?

The first step was a pre-test (see Appendix 7) in the form of multiple-choice questions and was used to establish learners' alternative conceptions. The pre-test is based on conceptual content of Energy and the Principle of Conservation of Mechanical Energy. It is a multiple-choice test with a combination of conceptual knowledge as a correct answer and alternative conceptions as distracters, because so far no test has been developed to test alternative conceptions alone. The test was also used to develop lessons for the intervention program. The pre-test had 10 multiple-choice questions with four options each.

(ii) To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?

The first and most significant step in teaching for conceptual change is to make learners aware of their own ideas about the topic under study. The pre-test was used to determine the learners' alternative conceptions and as a guide in the preparation of intervention lessons.

The lesson implementation followed, using the conceptual change approach. Three carefully prepared lessons (Appendix 8) incorporating practical work and computer simulations to support conceptual change teaching strategies were prepared and the sample population of thirty learners taught intensively. The interactive simulations were meant to support the students' learning of the Principle of Conservation of Mechanical Energy. These simulations were selected from the PhET website http://PhET.colorado.edu online free distribution. The basis for their selection was the contents of the concepts selected for this study. In short, the simulations were believed to support and make students interactive in their learning of the selected concepts for this study. The three lessons involved an exposition of the Principle of

Conservation of Mechanical Energy to allow learners to compare their conception with the scientific knowledge. All three lessons were prepared such that they meet the four conditions of conceptual change.

Lessons explored Gravitational Potential Energy; Kinetic Energy and the Principle of Conservation of Mechanical Energy. The four conditions of conceptual change were taken into consideration when the three lessons were prepared.

Table 4: Methodological Framework

RESEARCH QUESTION	RESEARCH METHOD	INSTRUMENT	RESPONDENTS	DATA ANALYSIS
(i) What are learners' initial understanding of the Principle of Conservation of Mechanical Energy concepts?	Pre- test	A pre-test is used to determine the learners' baseline knowledge & to generate ideas for intervention lessons	Learners	statistical analysis of the test scores
(ii) To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?	Intervention lessons	lesson plans are used to enhance understanding and promote conceptual change of concepts through the four stages of conceptual change which are: dissatisfaction, plausibility, intelligibility and fruitfulness	Learners	Evaluate concepts for dissatisfaction, plausibility, intelligibility and fruitfulness
(iii) What were learners' understanding of the Principle of Conservation of Mechanical Energy after the	A concept map	A concept map used to determine the effectiveness of the intervention	Learners	Statistical analysis of scores

conceptual change lesson?				
(iv) What were learners' perception of the conceptual change approach?	Focus groups semi-structured interviews	An interview schedule is used for triangulation	Learners	Transcribe, translate, categorise into themes, code

(iii) What were learners' understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson?

Learners had to construct concept maps after instruction to inform the interview items to be included in the interview schedule. They were told to take Mechanical Energy as the core (central) concept for their concept maps. Correspondingly, a list of concepts from the selected conceptual areas were provided to them in referring to the widely used standard textbooks for the grade. In addition to the concepts provided, the students were allowed to add more related concepts (if they had some) to their own concept maps. A memorandum for the concept map appears as Appendix 9.

(iv) What were learners' perception of the Conceptual Change Approach?

Semi-structured interviews were conducted in the researcher's school after the post-test. The interviewees were the same thirty Grade10 learners who participated in the conceptual change intervention. The thirty learners were grouped into five focus groups of six learners each. A focus group is defined as a research technique that collects qualitative data through group interaction on a topic determined by the researcher (Morgan, 1996). An interview schedule (see Appendix 10) was drawn up and face-to-face interviews conducted during lunch breaks. Interviewees were allowed to respond in the language of their choice and all responses were video-recorded. This study strengthens the data obtained with both quantitative and qualitative methods. This means, the results of the focus groups interviews help to understand the quantitative results of data collected with diagnostic pre-test and concept maps.

3.4.1 Data Collection Instruments

According to Cohen, Manion and Morrison (2008) there is no single prescription for which data collection instruments are to be used rather the choice should be "fitness for purpose". In order to collect data for this study, the following instruments were used to answer the research sub-questions:

3.4.1.1 Pre-test

The pre-test appearing as Appendix 7 was set. The conceptual content of the test was based on the following concepts: definition of Gravitational Potential Energy; definition of the Kinetic Energy and the Principle of Conservation of Mechanical Energy. Tests are means by which the presence, quality, or genuineness of anything is determined. A pre-test is a preliminary test administered to determine a student's baseline knowledge or preparedness for an educational experience or course of study. A pre-test is also used as a guide in the preparation of intervention lessons.

3.4.1.2 Concept Map

Concept maps formations in the selected conceptual areas of the Principle of Conservation of Mechanical Energy were another empirical data source of this study. As a research tool, concept maps were used to visualize the individual student's conceptions in terms of their graphic representation or organization and consequently evaluate their conceptual change of Mechanical Energy concepts.

The students were asked to construct concept maps after the intervention. They were told to take Mechanical Energy as the core (central) concept for their concept maps. Correspondingly, lists of concepts from the selected conceptual areas were provided to them in referring to the widely used standard textbooks for the Grade. In addition to the concepts provided, the students were allowed to add more related concepts (if they had some) to their own concept maps.

Before the creation of their actual concept maps, participants were given a training of 3 hours on the construction of concept maps. The contents of the training were focused on examining the purpose of concept maps, sharing examples of concept maps and a description of how to construct concept maps (Miller et al., 2009). During the training, concepts used as examples in the concept maps were not from the Principle of Conservation of Mechanical Energy concepts with the aim of not influencing the scores in their actual concept maps.

3.4.1.3 Interview Schedule

The other instrument used in the study was the interview schedule (see Appendix 9). Scott and Usher (2011) examines interviews as essential tools in educational research with pre-conceptions, perceptions and beliefs of social actors in education setting which form an important part of the backdrop of social interaction. Frey and Oishi (1995) define interviews as a purposive conversation in which one person asks prepared questions (interviewer) and another answers them (interviewee). According to Morse (1998) interviews can use the language that is best known to the respondent so that they can understand what is being asked. Semi-structured interviews were conducted on six focus groups of five learners each in order to get the deeper understanding of responses learners gave in the pre-test and in concept maps. Since interviews are conducted for a specific purpose, and are not an ordinary daily exercise (Dyer, 1995), the researcher arranged a convenient day and time with the participants well informed in advance, making sure there would be enough time for in-depth answers. The interview questions were planned but flexible in order to allow the response to form the basis of another question. The interviews were recorded. Beforehand, the researcher made sure the participants understood the nature and purpose of the study. The researcher obtained the participants' permission to record the interviews and assured them of the confidentiality. All gave their consent before the interview commenced.

Interviews were conducted in a secure and relaxed atmosphere so that the participants were able to talk freely and without interruption. This motivated the participants, and helped the researcher to collect accurate and trustworthy data. This is referred to as 'potential means of pure information transfer' (Kitwood, 1977, cited in Cohen, Manion, and Morrison, 2011:409). The learners participating in the research were interviewed during school breaks. The researcher interviewed the participants in a conversational way, structured and controlled by the interviewer to elicit implicit and explicit information that is related to the aims of the study. This is because the interview helps in not seeing participants as mere data who can be manipulated, but as subjects that can reason and generate knowledge which can be retrieved through interviews (Kvale, 1996).

The interview of the participants is most essential at this juncture because it allowed the researcher to gain an in-depth understanding of events and practices that were observed in the classroom. An interview schedule (see Appendix 10) was designed and it was used to determine the conceptual change and learning gains accomplished due to intervention. Six open-ended conceptual questions from the concepts of the Principle of Conservation of Mechanical Energy were prepared for the interview following Creswell's suggestion that "a few questions place emphasis on learning information from participants, rather than learning what the researcher seeks to know" (Creswell, 2008). Every member of the group was expected to participate actively in the interview. According to the progress made during the interviews, additional questions were also asked in some instances. Students were interviewed for between 20 and 30 minutes.

3.4.2 The intervention program

The first and most significant step in teaching for conceptual change is to make learners aware of their own ideas about the topic under study. The pre-test was used to determine the learners' alternative conceptions and as a guide in the preparation of intervention lessons.

The lesson implementation followed, using the conceptual change approach. Three carefully prepared lessons (Appendix 8) incorporating practical work and computer simulations to support conceptual change teaching strategies were prepared and the sample population of thirty learners taught intensively. The interactive simulations were meant to support the students' learning in the Principle of Conservation of Mechanical Energy. These simulations were selected from the PhET website http://PhET.colorado.edu online free distribution. The basis for their selection was the contents of the concepts selected for this study. In short, the simulations were believed to support and make students interactive in their learning of the selected concepts for this study. The three lessons involved an exposition of the Principle of Conservation of Mechanical Energy to allow learners to compare their conception with the scientific knowledge. All three lessons were prepared such that they meet the four conditions of conceptual change.

The three lessons explored Gravitational Potential Energy; Kinetic Energy and the Principle of Conservation of Mechanical Energy respectively. The four conditions of conceptual change were taken into consideration when the three lessons were prepared.

Dissatisfaction:

The lessons were introduced using an exposing event where learners were to make a hypothesis or answer questions and thereafter explain the basis of their prediction or answers. Group answers were supported with written descriptions that were presented to the whole class. For motivation in the learning process, correct answers with reasons for the choice were voted for by all the groups. The teacher would do an experimental demonstration that answered the question. This was done to prompt learner dissatisfaction with their original conception as the teacher and the learners evaluated all the groups' presentations. The conceptual change strategy was supported by the inquiry method, cooperative learning, discussions and direct instruction through scaffolding to provide a rationale for dissatisfaction with their original conception.

Intelligibility:

The scientific viewpoint could be considered, discussed, experienced and deliberated in groups A practical investigation or interaction with internet simulation was used for more understanding. During inquiry or investigations learners did activities individually, in pairs and in groups. It is important for the learner to become an active member of learning in the conceptual change model (Mistades, 2009). From the trends and relationships between quantities discovered learners could make more sense of what was taught and slowly reconstruct their conception such that it becomes acceptable in any situation.

Plausibility:

Energy is a quantitative concept. Learners were given a chance to do calculations based on Gravitational Potential Energy; Kinetic Energy; Mechanical Energy, Mass; Velocity or Height. Formulae used came from definitions and the Principle of Conservation of Mechanical Energy. After using simulations, students continued to discuss the events that related with energy concepts. In these discussions, the main purpose was to prove the usefulness of the learned conceptions. Gravitational Potential Energy and Kinetic Energy respectively were related to work done and the Law of Conservation of Energy was related to the Principle of Conservation of Mechanical Energy.

Fruitfulness:

In addition, with these simulations students learned the concepts deeply and made connections with real world situations and their prior knowledge (plausibility). To provide this, students tried to give some examples about the natural events and daily life experiences that are related to their new conceptions (fruitfulness of acquired concepts). This allowed learners the opportunity to consider the scientific viewpoint as plausible and intelligible. Learners were exposed to real life application of Gravitational Potential Energy; Kinetic Energy; conversion of Gravitational Potential Energy into Kinetic Energy and vice versa and a closed system. Through scaffolding learners were taught how the systems worked.

3.4.3 Pilot Study

To enhance both validity and reliability of the research instruments, a pilot study was carried out prior to the main study. Bell (2005:147), and McMillan and Schumacher (2001:185) remind researchers that data gathering instruments should be piloted in order to:

- Guard against validity and reliability,
- Ensure that the questions mean the same to all respondents,
- Estimate how long it takes the respondents to complete the questions,
- Check that all the questions and instruments are concise and clear,
- Check ambiguity in sentence,
- Check biased items, and
- Finally have direction.

The pre-test and the interview schedule were scrutinised by my supervisor to ensure their appropriateness as reliable instruments for collecting data. A pilot study using the revised instruments was then conducted on ten Grade 10 Physical Sciences learners in the neighbouring school. Learners in the neighbouring school were taught the Principle of Conservation of Mechanical Energy the similar way in which learners in the school under study were taught as teachers in the two schools prepare and sometimes co-teach together. Thereafter, learners in the neighbouring school were asked to comment on clarity, ambiguity and the level of difficulty of the questions. The exercise also helped the researcher to estimate the time that learners would spend in writing the test and in answering interview questions.

According to Mistades (2009), the reliability of concept maps is interpreted as the consistency of the scores on the various concepts given to students. To this end, the researcher and one senior lecturer in the field were used as raters. The two raters independently scored randomly selected conceptual maps of students before the actual scoring. The raters' agreement on the scores was compared for an estimation of inter-rater reliability. As a result, the scores were correlated and the inter-rater reliability estimate was 0.71, which was a reasonable result.

3.5 Data Analysis

Data analysis is described as a systematic process of selecting, categorising, comparing and interpreting data by sorting or organising collected data in order to verify the data, make sense of it, and ultimately to be able to draw conclusions from it (Patton, 2002).

The data analysis has been divided thematically according to the main research question with the help of the four research sub-questions namely: How can the teaching of the Principle of Conservation of Mechanical Energy through conceptual change improve learner conception? What are learners' initial understanding of the Principle of Conservation of Mechanical Energy concepts? To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy? What were learners' understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson? What were learners' perception of the conceptual change approach?

Both quantitative and qualitative data were presented in the themes. The qualitative analysis of the semi-structured, focus group interviews, and the quantitative analysis of the pre-test and the concept maps were administered to answer the research questions. Moreover, qualitative analyses results helped to understand and explain the quantitative results. In this study, data collected using the pre-test was quantitatively analysed first because of the need to use the students' scores in the test for the formation of focus groups for all the participants.

The data collected using the concept maps were also analysed quantitatively. Quantitatively, non-parametric statistical analysis was used to analyse test scores and concept maps, given the relatively small sample size of thirty learners from one classroom. The measure of central tendency on test scores and concept maps was used to statistically describe data using the mean, the mode and the median for the sample. In addition, data was statistically described using the histogram. To infer statistically if the conceptual change strategy made any significant difference in learners' test scores after the intervention, Standard deviation and variance were used.

Qualitative data analysis thus transforms data into findings (Sayser, 2014). The data collected by the focus groups interviews were qualitatively analysed. Data gathered from interviews was transcribed verbatim. A response from some of the learners that was captured in isiXhosa was translated into English.

Table 5: Data coding for interviews

Coding of learner's name	Coded text line	Focus group	Example of final code	Explanation
Learner 1 – L_1	Text Line4 – T_4	Focus Group 1 - FG_1	FG_1 L_1T_4	FG_1 – Focus group 1 L_1 - Learner 1 T_4 - Text line 4
Learner 2 - L_2				
Learner 3 – L_3				
Learner 4 – L_4				
Learner 5 – L_5				
Learner 6 – L_6				
Learner 1 – L_1	Text Line 20 – T_{20}	Focus Group 2 – FG_2	$FG_2L_3T_{20}$	FG_2 – Focus group 2 L_3 – Learner 3 T_2 – Text line 20
Learner 2 – L_2				
Learner 3 – L_3				
Learner 4 – L_4				
Learner 5– L_5				
Learner 6- L_6				
Learner 1 – L_1	Text Line 13 – T_{13}	Focus Group 3 – FG_3	$FG_3L_3T_{13}$	FG_3 –Focus group 3 L_3 - Learner 3 T_{13} – Text Line 13
Learner 2 – L_2				
Learner 3 – L_3				
Learner 4 – L_4				
Learner 5 – L_5				
Learner 6 – L_6				
Learner1 – L_1	Text Line 44 – T_{44}	Focus Group 4 – FG_4	$FG_4L_4T_{44}$	FG_4 – Focus group 4
Learner2 – L_2				
Learner3 – L_3				

Learner4 – L_4				L_4 – Learner 4 T_{44} – Text line 44
Learner5 – L_5				
Learner6 – L_6				
Learner1 – L_1	Text Line 19 – T_{19}	Focus Group 5 – FG_5	$FG_5L_3T_{19}$	FG_5 – Focus group 5 L_3 – Learner 3 T_{19} – Text line 19
Learner2 – L_2				
Learner3 – L_3				
Learner4 – L_4				
Learner5 – L_5				
Learner 6 – L_6				

The process of analysis started with reading to scan data and rereading of the transcripts from the audiotape recordings of the interviews to clean data. The transcripts were returned to the participants for confirmation and corrections. Some of the inaccuracies were corrected. Learner names, texts lines and focus groups were coded. L was the code used for learner, T for text lines in the transcript and F for the focus groups. For the thirty learners L_1 was the code for the learner 1 in each focus group and L_2 was the code for learner 2, etc. Text lines quoted from interview data were coded as T_1 for the first text line, T_2 for the second text line, etc. For the focus group to which the learners belong, F was used as a code. A focus group code for the learner in focus group 1 was F_1. The above codes are presented in table 5 below:

Thereafter, data from interviews were colour coded for themes that emanate. Thematic analyses emphasize, pinpoint and examine recording patterns (themes) within data. Themes then become patterns for analyses. It minimally organises and describes your data set in rich detail. However, frequently it goes further than this, and interprets various aspects of the research topic (Braun and Clarke, 2006). Thematic analyses capture something important about the data in relation to the research question and represent some level of patterned response or meaning within the data set (Braun and Clarke, 2006). Data for the study was analysed manually. Thereafter data was sorted into central themes.

3.6 Reliability

Reliability is the degree to which an instrument produces stable and consistent results. I ensured reliability in this study through the following:

I piloted the test and the interview schedule. Six respondents from the neighbouring school were requested to write the test and to be interviewed. I was able to detect if the language was clear, the questions were understood and unambiguous in the two instruments.

3.7 Validity

The validity of an instrument is very important in research. A valid instrument is one that measures what it is supposed to measure. Fraenkel and Warren (2000) assert that validity refers to the appropriateness, meaningfulness and usefulness of the specific inferences researchers made based on the data collected using an instrument. The validation of an instrument therefore ensures that the data collected using the instruments can be used to draw valid interpretations and inferences about the subject characteristics under study.

A pilot test was conducted and the face and content validity of the test were verified by two experienced lecturers of the field in the Department of Science Education at the University of the Western Cape and to one of the Science master teachers. As a result, they are found easy to understand by the learners. This was checked during the pilot test that no learner complained about interpreting the items because of their English knowledge.

I ensured that the aims and research questions are clear and focused and they linked well with the instruments. I sampled the population to ensure that there is good representation of respondents in the study. I used more than one instrument, a test and an interview schedule to triangulate the results. Triangulation is a good strategy to ensure validity.

3.8 Ethical Considerations

Steps were taken to ensure that the study conforms to the ethical standards laid down by the Senate Research Committee of the University of the Western Cape. Moreover, as per the requirement of the institution, a student conducting research as part of his/her study must seek ethical clearance from the University's Ethical Review Committee. Accordingly, a request for ethical clearance was made and approval was granted (see Appendix 1). Secondly, ethical clearance was asked from the Eastern Cape Department of Education to carry the research in their school (Appendix 2). Thirdly, permission was asked from the Principal of the school (Appendix 3). Fourthly, permission was also asked from the participating learners and their parents for consent (Appendices 4-6). The research participants were treated as autonomous individuals whose decisions on whether or not to participate were respected. The learners were informed that the research test scores were confidential and would have no impact on their classroom assessment. They were informed that the research test scores and any other means of data collection were confidential and will have no impact on their classroom assessment. The interview was anonymous with respect to the subjects' names. A confidentiality letter accompanied this to the respective school. The names of the school involved were kept anonymous. At the end of the study the school Principal and learners concerned will receive a summary report of the findings of the study conducted in their school.

3.9 Conclusion

This chapter described the research methodology including the research design, research sample, data collection instruments, issues of trustworthiness (validity and reliability of instruments), as well as methods of data analyses.

The next chapter will further discuss how data collected in this chapter will be used to bring forth findings that answer the research question.

CHAPTER 4

FINDINGS

4.1 Introduction

The previous chapter outlined the methodology employed to collect data. This chapter describes and analyses the data obtained through the administration of the various instruments, namely: the pre-test, the concept map, and the interview schedule from the purposely selected group of learners. All these processes were used to triangulate the data in order to produce trustworthy findings

The data analysis has been divided thematically according to the four research sub-questions. Firstly, data from the pre-test was used to expose learners' alterative conceptions and use them in planning for the intervention lessons to be conducted. Secondly, data from the concept maps were utilised to determine if the conceptual change approach supported learners in the process of discarding their alternative conceptions and using the universally accepted scientific concepts based on the Principle of Conservation of Mechanical Energy. Lastly, interviews were used to determine if the conceptual change approach of teaching was effective. Data analysis was informed by the theoretical framework underpinning the study, conceptual change. The data collected through the various techniques are intertwined in order to give a holistic account of the study. This chapter provides answers to the main research question:

How can the teaching of the Principle of Conservation of Mechanical Energy through conceptual change improve learner conception?

And the research sub-questions below address the main research question above:

(i) What are learners' initial understanding of the Principle of Conservation of Mechanical Energy concepts?

(ii) To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?

(iii) What were learners' understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson?

(iv) What were learners' perception of the conceptual change approach?

4.2 What are learners' initial understanding of the Principle of Conservation of Mechanical Energy concepts

As discussed in section 3.4.1.1 under methodology, the first aspect of the data analysis focuses on the learners' pre-test administered on conceptions in the Principle of Conservation of Mechanical Energy. A copy of the pre-test is attached as appendix 7. The pre-test consisted of ten multiple-choice questions based on four concepts. Questions one and seven were based on the concept, Energy; questions two, four and nine were based on the Gravitational Potential Energy; questions three, five and eight were based on the Conservation of Mechanical Energy; and questions six and ten were based on the formula of Kinetic Energy. The results of the test are reflected in table 6, table 7 and figure 3 below.

Table 6: Pre-test scores on the Principle of Conservation of Mechanical Energy concepts

Number of learners	30	Minimum score	5
Number of questions and total	10 20	Maximum score	13
Number wrote	30	Mean	6,9 (34,5%)
Number passed	18	Median	7(35%)
Pass percentage	60%	Mode	7
Average mark	7	Standard deviation	1,989
Average percentage	35%	Variance	3,957

According to Table 6, of the thirty learners that wrote the test that was out of twenty marks, 12 learners failed it (obtained less than 30%). The minimum and maximum scores obtained are three and thirteen, respectively. The mean score is 6,9, meaning that most learners obtained a score of seven.

The standard deviation is 1,9 and that means that the scores in the test differ by about 2 marks between the participants from the mean which is seven. The standard deviation implies that some learners obtained scores of nine while others obtained five, excluding the outliers like three and thirteen. The scores are clustered together between five (25%) and nine (45%) marks.

Table 7: Frequency distribution of total scores

Raw score	Number of learners	Percentage	Cumulative percentage
3	1	3,33	3,33
5	11	36,67	40
7	11	36,67	76,67
9	6	20	96,67
13	1	3,33	100

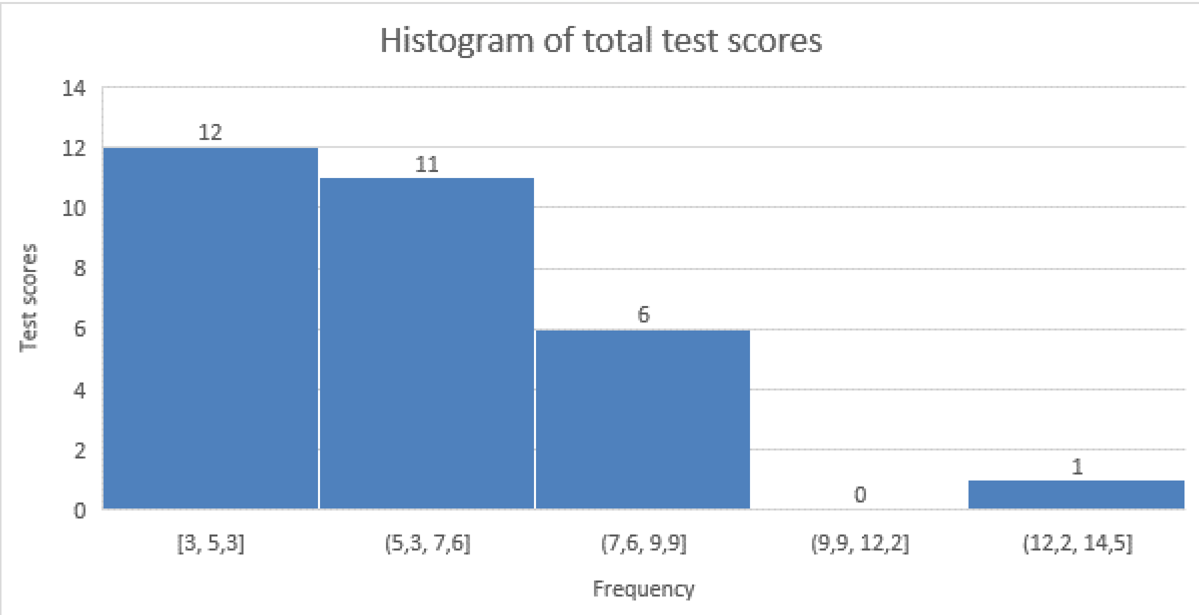


Figure 4: Frequency versus test scores graph

The scores obtained by learners were further distributed according to frequencies as shown in table 7 and figure 4 above where 22 of the 30 learners obtained between 15% and 35%. The results of the pre-test were further presented in figure 5 below where the performance of learners was based on question by question analysis in order to pick up alternative conceptions that learners had on the Principle of Conservation of Mechanical Energy. All the thirty learners answered question 7 correctly. In question 7 learners were asked to give the unit for Energy. On average, twenty of the thirty learners obtained questions 1, 2 and 3 correctly. Question 1 was about identifying the two main forms of Energy. Questions 2 needed the understanding of Gravitational Potential Energy that it depends on mass and height above the reference point. Question 3 was about Energy conversion from Gravitational Potential Energy to Kinetic Energy. On average again, five learners obtained questions 4, 5, 6, 8, 9 and 10 correctly. The questions were either about the understanding of Gravitational Potential Energy, Kinetic Energy, Mechanical Energy or application of these concepts in new contexts.

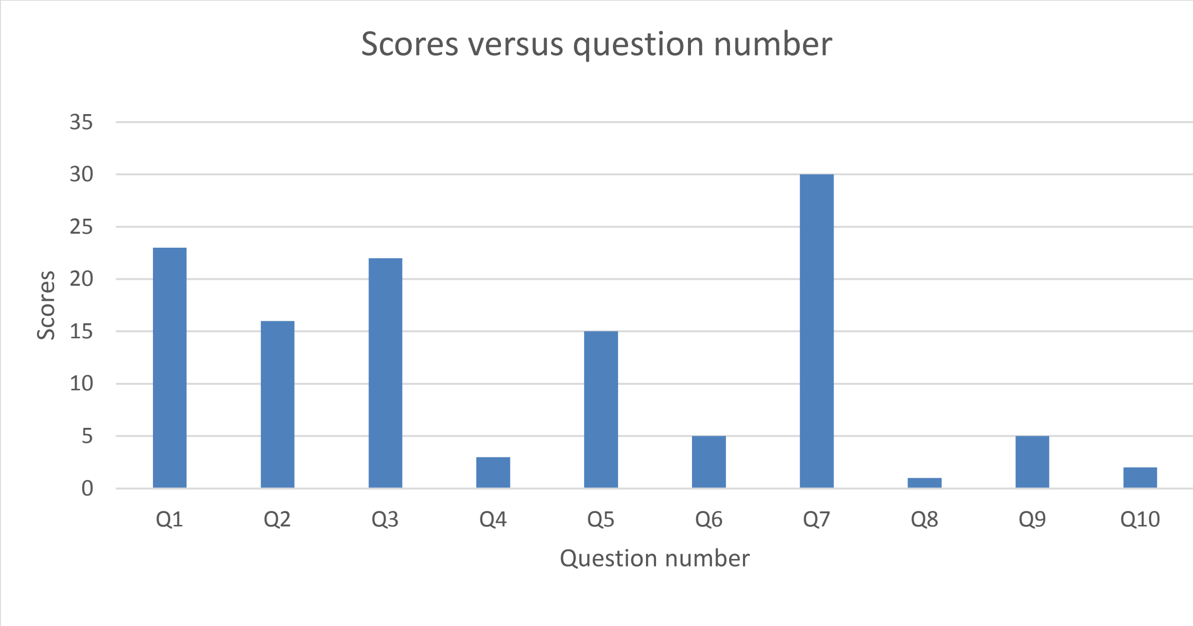


Figure 5: Average marks per question expressed as a percentage

4.3 To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?

To improve the conceptual understanding of the Principle of Conservation of Mechanical Energy concepts by learners, the conceptual framework was followed. According to Posner et. Al. (1982) there are conditions that must be met in order for conceptual change to be successful. Teaching for conceptual change is supposed to: (1) provoke learners' dissatisfaction toward their own misconceptions by any means necessary (as in Nussbaum's "exposing event" [1982]), and then present the scientific conception to learners in order for it to be (2) intelligible, (3) plausible, and (4) fruitful. The four conditions for conceptual change during intensive teaching of the three different lessons were taken into account.

4.3.1 Dissatisfaction

In lesson1, learners were asked in groups of six learners each to make a hypothesis based on the quantities on which the magnitude of the Gravitational Potential Energy depends and then give the basis of their predictions.

At the beginning of the lesson four of the five groups were not sure as to whether their predictions were correct or not and as a result were not confident enough when presenting their predictions. Only one group knew that the magnitude of Gravitational Potential Energy depends on height above the reference point and on mass. This group could justify their prediction using the formula for Gravitational Potential Energy. This was the hypothesis that was voted for by all groups. The formula for calculating Gravitational Potential Energy was used by the teacher and the learner groups as a yardstick for determining whether all other hypotheses were correct.

The other predictions were:
"Gravitational force depends on mass and height."
"The higher the object is from the reference point, the stronger the gravitational force."
"Different objects placed off the earth surface with different masses will have similar Gravitational Potential Energy."
"Gravitational Potential Energy is determined by mass and position of an object."

Learners were dissatisfied with the hypotheses presented by all the other groups. The reasons given by learners for not accepting these hypotheses were:

> The hypotheses were not in line with the Gravitational Potential Energy formula. [Learner 1]
>
> The concepts used in the place of Gravitational Potential Energy like force of gravity and gravitational pull are incorrect. [Learner 2]
>
> This hypothesis does not show any relationship between quantities. [Learner 3]

There was a group of learners that did not take the testing of their hypothesis well and ended up disturbing others by making noise instead of concentrating on the task at hand and respecting the genuine views of others.

In lesson 2, the thirty learners were divided again into five groups of six learners each. Learners were asked to discuss the following questions and present their answers to the whole class:

If two objects with similar mass are dropped from different heights, which one will have the higher velocity as it hits the floor?

If two objects with different masses are dropped from the same height, how will their velocity compare as they hit the floor?

The answers to the first question were as follows:

Both objects will hit the floor at the same velocity. [Learner 1]

An object dropped from a smaller height will hit the floor with a higher velocity. [Learner 2 and Learner 5]

An object with a greater height will hit the floor with the higher velocity [Learner 3 and Learner 4]

The answers to the second question were:

The object with a greater mass will hit the floor with a higher velocity. [Learner 1 and Learner 5]

Objects will hit the floor at a higher speed. [Learner 2]

The object with a smaller mass will hit the floor with a higher velocity. [Learner 3]

The smaller object will hit the floor with a higher velocity. [Learner 4]

The teacher did a practical demonstration that answered the questions asked above. The teacher made plasticine into a flat rectangle of about 1cm thick. In the first round, two marbles of the same mass were dropped from different heights onto the plasticine. Dents were made on the plasticine. The depth of the dents was used as a measure of Kinetic Energy. In the second round, two marbles of different masses were dropped from the same height onto the plasticine. Observations were made and written by the teacher on the chalkboard.

Observations made were that the greater the mass of the object, the higher its kinetic energy. Also, the greater the velocity of the object, the higher its kinetic energy. Below were the answers to the two questions above:

The object from the greater height had the higher velocity.

The object with the greater mass had the higher velocity.

Learners were asked by the teacher to revisit their responses to the two questions asked above to check if they were the same as the answers coming from the observations of the demonstration. Learners had the following to say about the answers they gave for the first question before the teacher demonstration:

> We thought that height does not influence velocity. [Group 1, Learner 3 and Group 4, Learner 1]
>
> We had a question that how can an object dropped from a greater height increase in velocity? [Group 2, Learner 2]

We were not sure of the answer. We were just guessing. [Group5, Learner 1]

Below are the learners' comments regarding the responses given for the second question after the teacher demonstration:

> We used the formula for Kinetic Energy to get this relationship. [Group1, Learner 2 and Group 4, Learner 2]
>
> We did not consider the different masses of the objects dropped but the same height from which they were dropped. [Group 2, Learner 5]

In lesson 3, learners were divided into groups of six learners each and the total of five groups were formed. The teacher asked the learners to discuss the following questions based on the statement below and present their answers to the whole class:

As the book falls its velocity increases. What happens to its kinetic energy as it falls? What happens to its gravitational potential energy as it gets nearer to the ground?

This is how the learners answered the above questions:

> As the book falls kinetic energy increases and potential energy does not change. [Group 1, Learner 3 and Group 3, Learner 1]
>
> As the book falls kinetic energy decreases and gravitational potential energy also decreases. [Group 2, Learner 3]

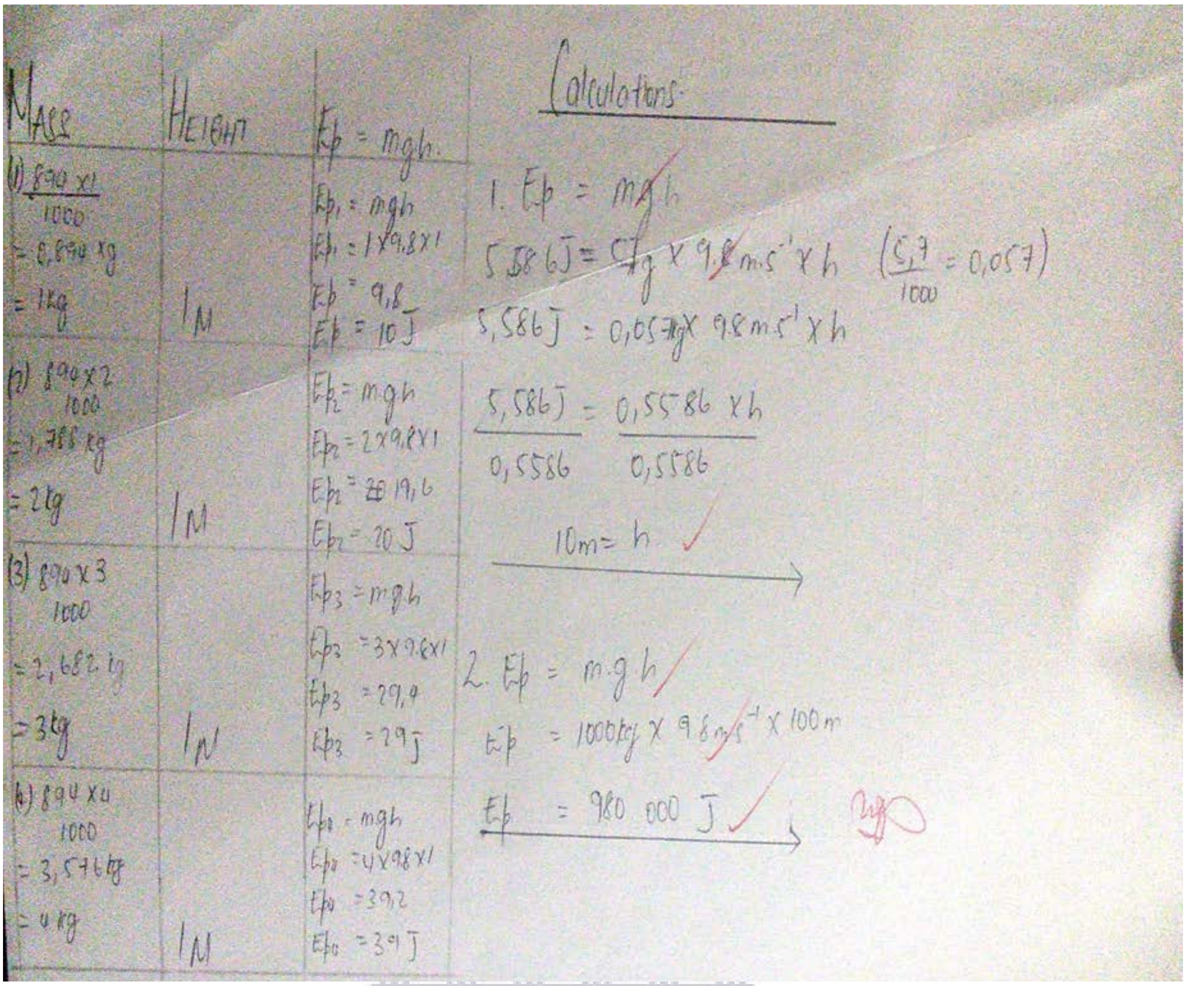
Firstly, in only one of the three lessons taught were learners able to make predictions of the outcomes based on the relationship between quantities that define either Gravitational Potential Energy, Kinetic Energy or Mechanical Energy. Secondly, either the internet interactive pHET simulations or practical investigations were used as an exposing event in all three lessons. Lastly, in all three lessons learners were able to compare their observations with their initial predictions.

4.3.2 Intelligibility

Practical investigations and internet interactive simulations were used in assisting learners to make sense of the new concepts introduced to them during the exposing events so that they can accommodate them in their conceptual frameworks.

A worksheet on Gravitational Potential Energy was handed out (see Appendix 11) to learners in lesson1. Learners were hands on doing a practical investigation based on the correct hypothesis on Gravitational Potential Energy. All the groups investigated the relationship between mass, height and gravitational potential energy. At first mass pieces of the same mass were lifted to different heights and data collected. Secondly, mass pieces of different masses were lifted to the same height and data recorded. Thereafter the teacher grouped the learners in pairs and asked them to draw graphs that relate the independent and the dependent variables using the data collected during the investigation. Lastly, learners were asked by the teacher to draw conclusions and were compared with the hypothesis.

Below is the learner's script (see Figure 6) and some of the comments from the learners after the practical investigation on Gravitational Potential Energy:



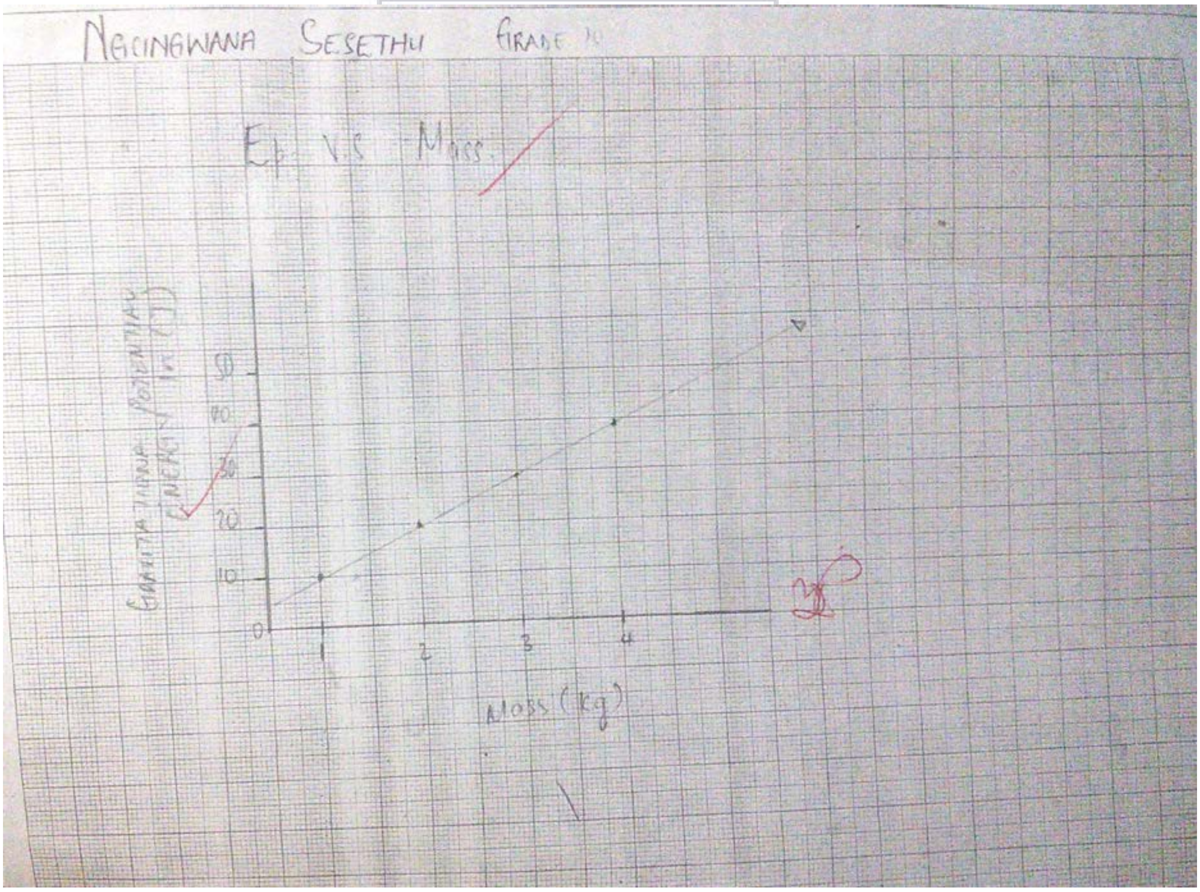


Figure 6: Sample of learner's data table, graph & calculations

Being hands on using physical quantities like mass and height in order to determine Gravitational Potential Energy helped me understand Gravitational Potential Energy better. [Group3, Learner 4]

The collected data on the table showed me trends that if either mass or height increases, gravitational potential energy will also increase. The trends shed more light on the fact that either mass and height are independent variables and Gravitational Potential Energy is the dependent variable. [Group2, Learner 5]

The tables and graphs gave a clearer picture of the Gravitational Potential Energy concept. [Group4, Learner 1]

I now understand Gravitational Potential Energy better. [Group1, Learner 5]

I heard from the teacher and my peers, I saw with my eyes and now I understand this concept better. [Group 5, Learner 4]

In lesson 2, learners in the five groups were asked to do a practical investigation to determine the kinetic energy of marbles with different masses and velocities by observing the dents formed when marbles fell onto the plasticine. The practical activity was repeated three times. Following this activity, learners were grouped in pairs again and were asked to draw conclusions based on their observations. Back in groups again, learners were asked by the teacher to write their conclusions in symbol form, as a formula that they can use to calculate kinetic energy.

As learners were doing the practical investigation repeatedly, here are some of their comments:

Doing this activity over and over again helped me to understand the topic better. [Group4, Learner 4]

The practical activity on Kinetic Energy improved my understanding of the concept. [Group 1, Learner 3]

Conducting the investigation, has helped me to learn at my own pace and now I understand better. [Group 3, Learner 1]

It became easy to draw a conclusion because I understand what Kinetic Energy is about. [Group 1, Learner 6]

In lesson 3, the teacher asked the learners to meet at the computer laboratory. In the laboratory the teacher gave them time to explore the internet interactive simulations that show energy conversions in a pendulum between Kinetic Energy and Potential Energy and their values and vice versa. The interactive simulation they worked on is portrayed in figure 7 below:

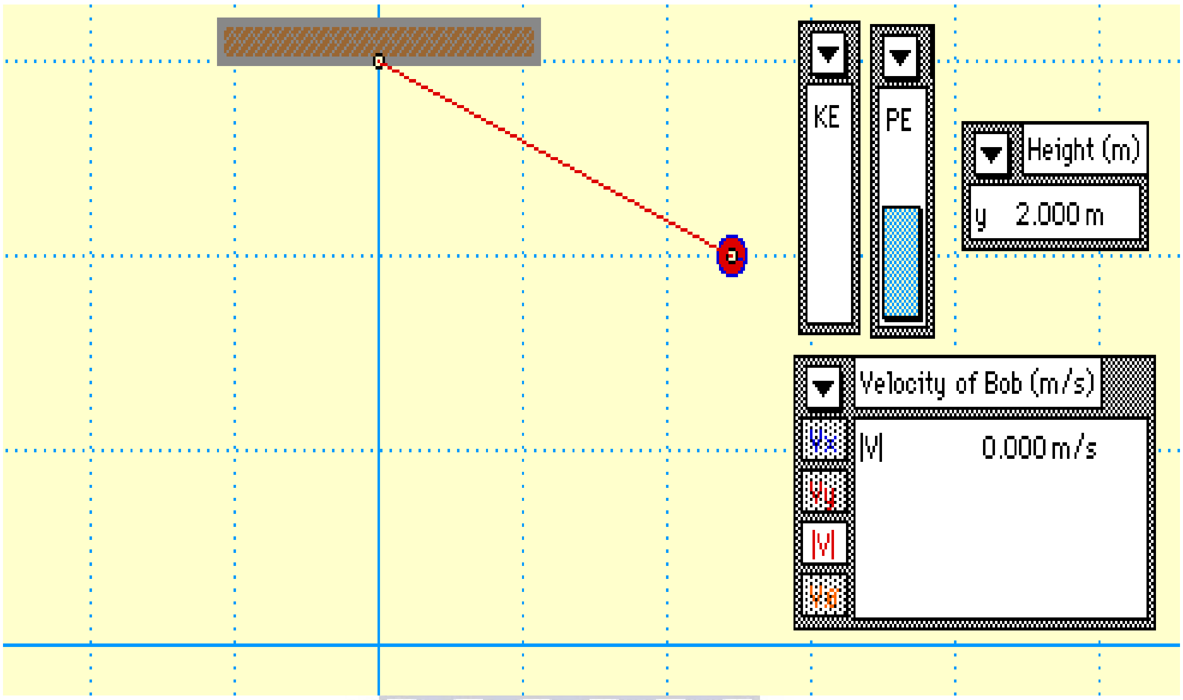


Figure 7: A pendulum and Conservation of mechanical energy

In groups, the teacher asked the learners to determine if the sum of their values at any point remained constant. Lastly, the teacher asked the learners to form groups again. The teacher asked the learners in groups to write a mathematical statement as a conclusion about mechanical energy at any point in the system when there are no external forces acting on the system.

Technology is part of the learners' lives as they live in a technologically advanced era. All the learners were excited for being invited to learn using technology. Be that as it may, they did not forget why they were there. Below are the utterances that I picked up from some of them:

> If we can learn using computers every day, I can understand all topics better. [Group5, Learner 6]
>
> I went back and forth checking the values for gravitational potential energy, kinetic energy and mechanical energy and that helped me understand the Conservation of Mechanical Energy better. [Group3, Learner 3]
>
> Looking at the values I could see that at any point in the system, mechanical energy remained the same. [Group 2, Learner 4]

The fact that there was no change in mechanical energy in the same system at different points convinced me that mechanical energy is conserved when there are no dissipated forces. [Group4. Learner 1]

4.3.3 Plausibility

As learners learnt intensively about the concepts on the Principle of Conservation of Mechanical Energy, it became important that they should not only understand these concepts but also be able to apply them in new situations in order for them to be plausible. In trying to attain plausibility learners had to do the following activities.

In lesson1. The teacher asked the learners to use the available resources like textbooks, science dictionaries and the internet browser to define the following concepts: Energy, Gravitational Force, Distance and Height. Thereafter the teacher probed a discussion on the relationship between work done and energy using the definitions given by learners. Learners were then asked by the teacher to do calculations on gravitational potential energy using the formula $E_p = m.g.h.$ in different unfamiliar situations and below are their remarks after solving all the given problems:

It is easy to solve all these problems as long as you are able to analyse the data from the statement given. [All the groups]

We know how to change the subject of the formula and that makes it even easier to solve for any variable in the formula. [Group4, Learner 3; Group 4, Learner 6]

As we did the calculations we saw how mass and height affects the gravitational potential energy and that helped us to understand the concept even better. [Group5, Learner 2]

The formula was applicable in different situations. [Group 1, Learner 5]

In lesson 2, the teacher asked the learners to individually calculate kinetic energy or velocity using the formula: $E_k = ½ m.v.^2$ in new situations. Next, learners were asked by the teacher to use the observations made during the practical investigation on kinetic energy and interchange kinetic energy and work done in moving an object from one position to another. Below are the learners' utterances as they do calculations on kinetic energy:

With mass and velocity given in the statement, it becomes easy to calculate kinetic energy. [Group 2, Learners 1 & 4]

The formula for kinetic energy has three quantities. If any two of the three quantities are given in the statement, it becomes easy to work out the third quantity. [Group 1, Leaner 5]

I enjoy doing these calculations now that I understand the topic better. All the other questions required the correct scientific understanding of the concepts. [Group 4, Learner 3]

Learners also made the following comments concerning the relationship between kinetic energy and the work done on an object:

When the velocity of an object increases or decreases, kinetic energy changes. [Group 5, Learner 2]

I think that kinetic energy changes because work has been done. [Group 2, Learner 4]

Mam, I think this means that work is done whenever there is a change in kinetic energy. [Group 3, Learner 1]

In lesson 3, the teacher asked the learners to individually calculate the value of the unknown in the formula: $(m.g.h. + ½\ m.v.^2)_{at\ A} = (m.g.h. + ½\ m.v.^2)_{at\ B.}$ Thereafter, the teacher asked the learner groups to search for the meaning of the following concepts from the internet: dissipative forces and a closed system. Lastly, the teacher asked the learners in pairs to explore the law of conservation of Mechanical Energy in the absence of dissipative forces and report on their findings. As far as the calculations are concerned, learners had this to say:

I enjoy doing calculations as I understand the concepts better. [Group 4, Learner 4]

We all finished doing the calculations before the set time. [Group 3, Learner 2]

The report on the Law of Conservation of Mechanical Energy in the absence of dissipative forces was that:

Mechanical energy at one point is the same as mechanical energy at another point that is in the same system in the absence of dissipative forces [Group 5, Learner 3]

Mechanical energy remains the same at two different points of the same system when there are no dissipative forces. [Group 1, Learner 1]

Mechanical energy at A is equal to mechanical energy at B when there are no external forces. [Group 4, Learner 3]

When mechanical energy does not change, that means there are no dissipative forces. [Group2, Learner 5]

4.3.4 Fruitfulness

Teaching and learning in schools take place most of the time in classrooms. This implies that knowledge is acquired in the classroom. One of the aims of education is to apply the acquired knowledge in everyday life. The starting point is when the learner is able to identify objects in everyday life where the knowledge gained in the classroom is used in everyday life out there. In the last stage of intensive teaching, learners were exposed to real life objects or their images where Gravitational Potential Energy, Kinetic Energy and Mechanical Energy concepts were in action.

From the real life examples displayed in the classroom and from the internet (see Figure 8 below) learners could identify images of objects at rest, moving objects at different positions from the reference point, objects of different masses being dropped from the same height and systems that show mechanical energy that was conserved. Below are such examples

:


ENERGY IN SIMPLE HARMONIC MOTION

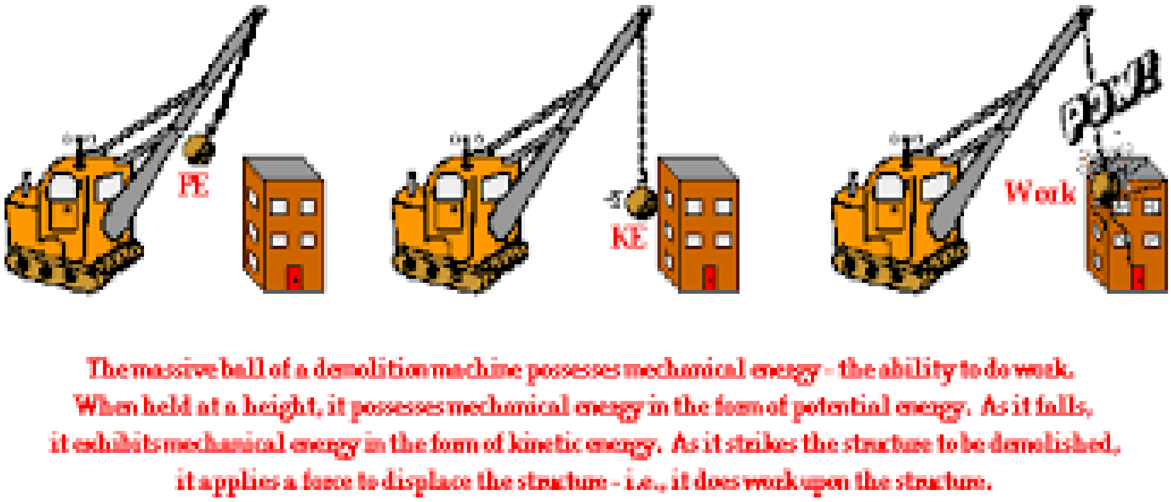


Figure 8: Real life examples of Mechanical Energy

Learners had this to say about the real life examples:

> Science is now alive. We know why we need to learn about Energy. [Group4, Learner 5]
>
> I could tell what is happening in each image because I understood the different Energy concepts and how they are related. [Group1, Learner 4]
>
> Real life examples excite me because what I learnt about energy is exactly what I have discovered here. [Group 3, Learner 2]
>
> A pendulum, wall clock conserves Mechanical Energy if its system is closed. [Group 5, Learner 1]

4.4 What were learners’ understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson?

Concept maps were used to elicit information from the learners, to give them a chance to explain how and why they understood concepts on energy in particular ways (see Appendix 11).

The descriptive statistics of the students’ scores with respect to the components of concept maps were analysed (see Table 8). The propositions, hierarchies, cross-links and examples that appeared on every participant’s concept map were scored quantitatively based on the scoring rubric (see Appendix 8) in which each concept map component was measured from 0 (minimum) to 4 (maximum). Hence, the total maximum score of a student would be 16. The average students’ score was converted to percentage for the purpose of comparison with the other results.

Table 8: Descriptive statistics of students' concept maps scores

<table>
<tr><th>Concept map components</th><th>N</th><th>Minimum</th><th>Maximum</th><th>Mean</th><th>Standard deviation</th><th>Variance</th></tr>
<tr><td>Propositions (out of 4)</td><td>30</td><td>2</td><td>4</td><td>3,067</td><td rowspan="5">1,408</td><td rowspan="5">1,,982</td></tr>
<tr><td>Hierarchies (out of 4)</td><td>30</td><td>3</td><td>4</td><td>3,433</td></tr>
<tr><td>Cross links (out of 4)</td><td>30</td><td>2</td><td>4</td><td>3,133</td></tr>
<tr><td>Examples (out of 4)</td><td>30</td><td>3</td><td>4</td><td>3,233</td></tr>
<tr><td>Total (out of 16)</td><td>30</td><td>11</td><td>16</td><td>12,867 (80,419%)</td></tr>
</table>

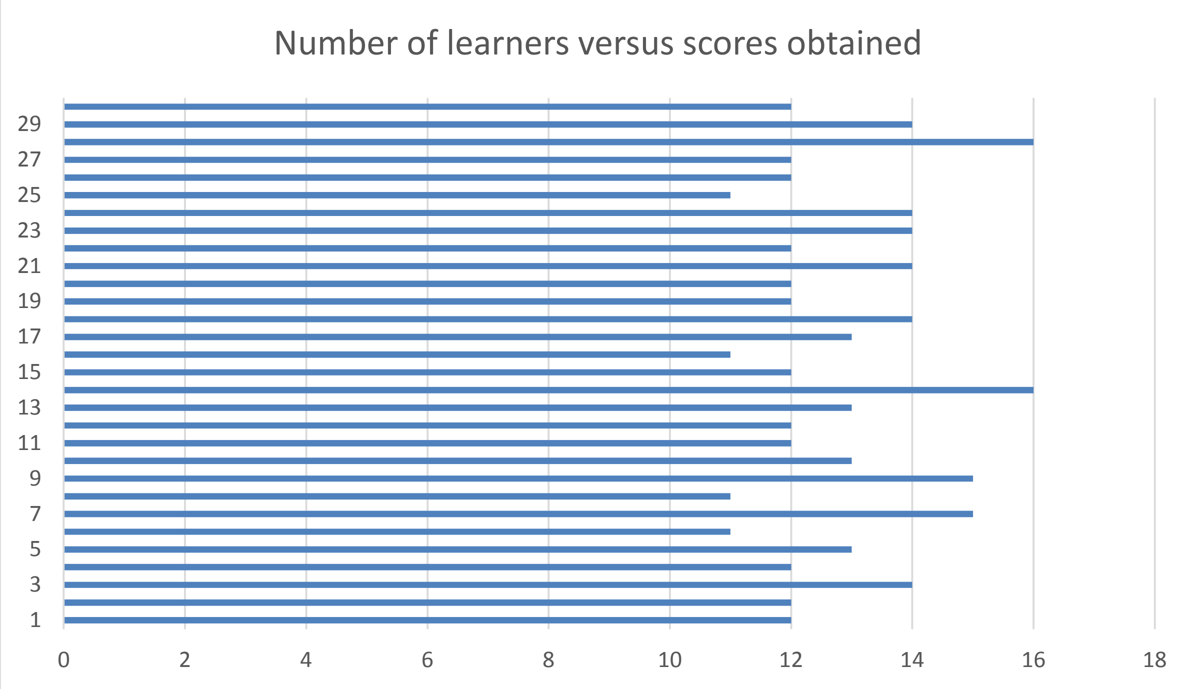


Figure 9: A cluster graph of the number of learners versus the scores obtained

As shown in Table 6, the learners' mean score on the pre-test was 34,5%. The mean of the concept maps is 80,419%. The results of the learners' test scores represented their conceptual knowledge before the intervention programme. In addition, the results showed that the conceptual knowledge of the learners represented by the pre-test were just low and that implied that the learners lacked in-depth conceptual understanding of the Principle of Conservation of Mechanical Energy concepts. The mean score of the concept maps is 80,42%. The mean shows that most learners did well in concept maps by scoring 12 out of 16 marks. In addition, it also means that there was an improvement of 45,92% in the learners' in-depth knowledge of the Principle of Conservation of Mechanical Energy concepts. The minimum score obtained by learners (see Figure 9) on concept maps is 68% (11 marks) and is above the mean of the pre-test. The maximum score is 100% (16 marks) and is also above the maximum score of 65% (13 marks) in the pre-test. The standard deviation and variance decrease from 1,989 in the pre-test to 1,408 in concept maps and 3,957 in the pre-test to 1,982 in concept maps respectively. That means that learners' scores deviate by about 1 mark from the mean and between learner and learner in concept maps.

4.5 What were learners' perception of the conceptual change approach?

Information from interviews allows for better understanding of the process of conceptual change, and the resultant triangulation of the data serves to enhance the research findings. The interviews targeted thirty learners that were divided into five focus groups as explained in the methodology section. These semi-structured interviews focused on participants' views about the conceptual change teaching strategy and its effects on their understanding of the Principle of Conservation of Mechanical Energy concepts. There were some prepared questions that assisted the researcher in answering the research questions. But during the interviews some other questions ensued, depending on how the learners answered the preceding ones. Some of the major and relevant answers to the questions are presented below in relation to the themes that emerged.

The themes that emerged during interviews of respondents are presented and analysed. In this section, emerging themes are presented. They are: unhappiness, doubt, learners not meeting expectations, better understanding of concepts, concept expressed in different ways, and the impact of real life examples on concepts taught in the classroom. These will be dealt with separately.

4.5.1. Unhappiness

Once a concept does not make sense to the learner during the teaching and learning process, the learner panics and becomes unhappy. The interviewees below shared the same sentiments.

> *I am not happy with the first prediction which was about gravitational potential energy. Our prediction did not show the relationship between height and gravitational potential energy. It only stated that the object above the earth's surface has gravitational potential energy.* [$FG_1L_2T_{22}$]
>
> *we meant the height of the object.* [$FG_5L_2T_{174}$]
>
> *We were not happy with the fact that we did not relate gravitational energy and height or mass or relate gravitational potential energy with both mass and height.* [$FG_5L_5T_{175}$]

FG_1L_2; FG_4L_5; FG_5L_5 and FG_5L_2 were unhappy with their prediction or hypothesis in the first lesson of the intervention programme that was about the Gravitational Potential Energy concept. The number of unhappy learners about relating energy concepts and formulating predictions dropped to two learners in the last lesson, the lesson on Mechanical Energy. This means that the Gravitational Potential Energy concept was most challenging to the learners in the sense that learners could not easily let go of their existing alternate conceptions.

4.5.2 Doubt

Another theme that emerged is doubt. When a concept is new to the learner, the learner will doubt whether to believe or reject the new information and that is evident in the response that he or she gives about that concept because the concept is not yet accommodated in the learner's conceptual framework. Doubt is revealed in the following responses:

> *I was not sure whether the second prediction was right or wrong but knew that the third prediction was correct.* [$FG_1L_5T_{23}$]
>
> *I was not yet sure that we were dealing with mathematical concepts where I could use the formula for kinetic energy to help me make a prediction.* [FG_1L_6T25]

Some of the group five learners voiced out their doubt. To my observation, group 5 learners were not the only ones that were doubtful. Whenever they were not sure of a concept, some other groups were not sure too.

4.5.3 Learners not meeting expectations

The next theme that emerged is that of learners not meeting expectations. Scientific concepts under the same topic can be related to form new concepts that make more sense. A hypothesis relates concepts. Below are what learners had to say about formulating a hypothesis:

> … *we did not relate gravitational energy and height or mass or relate gravitational potential energy with both mass and height. Our prediction was that the higher the object is from the reference point, the stronger the gravitational force.* [$FG_5L_5T_{171}$]
>
> … *we did not relate gravitational potential energy and height or mass. We related the force of gravity with mass and height.* [$FG_3L_1T_{107}$]

The two learners could not get their predictions correct without relating Energy concepts. All the other learners got it right although they were not aware that they were relating concepts.

A formula carries a lot of information about quantities involved. To most learners that participated in the intervention programme a formula is meaningless. Only one focus group out of the five groups had a better and deeper understanding of the formula.

> *Our predictions about gravitational potential energy was that as the mass of an object increases, gravitational potential energy will also increase.* [$FG_2L_5T_{66}$]
>
> *… kinetic energy is directly proportional to velocity*. [$FG_2L_2T_{67}$]

Focus Group 2 was the only group that used the formula to make predictions from the first lesson. No one told or suggested formulae to them. Other groups started using formulae to make predictions in the next lessons after learning it from focus group 2.

4.5.4 Better understanding of concepts

The next theme that also emerged was better understanding of concepts. Teaching plays a big role in equipping learners with knowledge. A learner can also be equipped through doing practical work and interacting with internet simulations. A learner is not only hands on when doing a practical investigation or working with simulations, a learner also thinks about what he or she is doing. This learning process helps the learner to construct meaning for better understanding of concepts.

> *The teaching in the classroom and practical work helped us to understand better because we were able to see what we were talking about.* [$FG_1L_3T_{29}$]
>
> *It is the practical work in the classroom and interactive simulations in the computer laboratory.* [$FG_2L_2T_{73}$]
>
> *Simulations and practical work helped us to understand the energy concepts clearly.* [$FG_4L_1T_{146}$]

In two of the three responses it is evident that learners make more meaning of what they learn from practical work and simulations, i.e. when they construct it themselves.

4.5.5 Concepts expressed in different ways

Another theme that emerged is: concepts expressed in different ways. Formulae help us define concepts and to do calculations that quantify those mathematical concepts. Concept maps can also be used to link and visualise concepts. A taste of how concepts are expressed is given below:

> *Energy concepts could also be defined using formulae.* [$FG_1L_1T_{35}$]

I think that one can also use graphs. [FG1L5T36]

We could use formulae. [FG2L1T77]

We could use concept maps. [FG2L4T78]

Other than using words I could define energy concepts using formulae. [FG4L3T151]

A concept that withstands rigorous testing as expressed by interviewees above becomes accepted by the science scholars and is added to the body of scientific knowledge.

4.5.6 Impact of real life examples on concepts taught in the classroom

The other theme that emerged is the impact of real life examples on concepts taught in the classroom. Learners were shown real life examples of the scientific concepts learnt in the classroom. Learners were made to understand that science does not end in the classroom but forms part of our everyday life. Learners responded this way when they were given a chance to explore the real life examples:

We realised that kinetic energy and gravitational potential energy is all around us and they are in everything that we come across or use every day of our lives. [FG1L3T40]

Real life examples made concepts like gravitational potential energy and mechanical energy more understandable. [FG3L3T119]

I feel more confident. I think I can solve any problem on the principle of conservation of mechanical energy. [FG3L1T120]

Real life examples made me realise that mechanical energy forms part of our lives. Whatever we do, when objects move or remain stationary. [FG4L2T154]

The learners' responses show that using real life examples make concepts more understandable and builds confidence about the concept learnt. Learners realise the importance and applicability of science in the real world and that arouses the curiosity and interest of learners to learn more about the concept

4.6 Conclusion

This chapter presented and analysed data obtained through the pre-test, concept map and the interviews. The baseline results of the test scores were the first ones to be presented and were to be used in the planning and preparation for the intervention programme. After the intervention programme, concept maps and focus group interviews' data were also presented and analysed using statistics and the framework thematic analysis. Six themes were identified and used to measure the effectiveness of the intervention. The results presented in this chapter will be discussed in the next chapter.

CHAPTER 5

DISCUSSION

5.1 Introduction

In the previous chapter, the qualitative and quantitative findings of the study were presented. Those findings were mainly used to answer the main research question. The purpose of this study is to explore the conceptual change approach in the teaching of the Principle of Conservation of Mechanical Energy (in the absence of dissipative forces) to see if it cannot address the challenge of conceptual understanding in the topic. This chapter critically discusses the findings, linking them to the relevant literature. The discussion is presented around the research questions. In this chapter research question (i) will concurrently be discussed with research question (iii). Next, the discussion of research questions (ii) and (iv) will follow. Lastly, the conclusion will close the chapter.

5.2 What was learners' initial understanding of the Principle of Conservation of Mechanical Energy compared to learners' understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson?

Conceptual change is a teaching strategy. Like any other teaching strategy, it requires prior planning. The baseline information about what the learner knows or does not know is necessary for lesson planning. As displayed in Table 6 and Table 8 respectively, in one hand, learners' scores range between 3 and 13 (out of 20) with the statistical mean of 6,9 (34,5%)for the pre-test. On the other hand, learners' scores range between 11 and 16 (out of 16) with a statistical mean of 12,87 (80.42%) for the concept map. What this means is that the average score obtained by 20 (66,6%) out of 30 learners in the pre-test is seven out of 20 marks, and it is clearly depicted in the histogram of total scores in figure 4. In contrast, 22 learners (73,3%) out of 30 learners scored between 12 and 14 out of 16 marks in concept maps. The mean score depicted from the concept map scores indicates an improvement in the conceptual understanding of the Principle of Conservation of Mechanical Energy by learners. Learner improvement in conceptual understanding was evident after the intervention lessons.

On one hand, the standard deviation of 1,9 in the pre-test means the variation in scores from the mean is small (about 2marks) and that only 33,3% of leaners did not obtain a score of 7 marks. What this implies is that only 10 learners obtained a score that is either above or below 7 marks. The minimum score obtained by learners is 3 (15%) and the maximum mark is 13 (65%). Learners' scores spread out between 3 and 13

These findings signify that learners' pre-conceptions vary widely. Learners tapped on their prior knowledge crammed with alternative conceptions on the Principle of Conservation of Mechanical Energy when answering questions in the pre-test. There were alternative conceptions that they were still holding on to. This baseline information is necessary if the teacher is to teach Science concepts for conceptual change. The fact that learners did not do well in the pre-test does not mean that a learner comes to the classroom with an empty mind. There are some scientifically correct concepts in the learner's conceptual framework that the learner brings. This suggests that learners bring alternative conceptions that need to be corrected in the classroom because if not, conceptual change will be hindered. Thus, it is the responsibility of the teacher to help the learner to consciously discard the alternative conceptions and actively learn the scientifically correct concepts. (Robottom, 2004; Duit,1999; Brophy, 1992) reported that learners come to the Science class with their own ideas, beliefs, and understanding of how things work, and therefore learning is not to fill the learner's head with information and data, but to change or work with their existing ideas and beliefs. Learning is seen by Robottom (2004) as conceptual change.

On the other hand, the standard deviation of the concept map scores is 1,408 and is smaller than that of the pre-test. This means that the scores vary by about 1 mark from each other and that there are few learners that obtained scores that are either above 14 or below 12. Table 8 also displays the mean scores for the four components of the concept map and they vary between 68,75% and 100%

The significance of these findings is that the conceptual change intervention lessons helped the learners to restructure their conceptual framework after evaluating and discarding the alternative conceptions by reconciling and accepting the correct scientific concepts, hence the improvement in learner performance (Bruning, Schraw & Ronning, 1999; Scott, Asoko & Driver, 1991).

These findings were further confirmed in the question-by-question analysis of the pre-test appearing as figure 4 where each and every question was scored by at least one or more learners. Only question 7 was scored by all the learners. Question 7 was a level 1 question that asked for the unit of energy (rote learning).

The descriptive statistics on learner performance in concept maps reveal that the intervention programme had a positive impact on the conceptual understanding and an in-depth knowledge of mechanical energy concepts as seen in Table 8 above as compared to their conceptions before the intervention. The increase in the mean score and the decrease in standard deviation shows an improvement in the use of scientifically correct concepts on the Principle of Conservation of Mechanical Energy after the intervention undertaken by all the learners. The effectiveness of the conceptual change teaching approach is also reported on in the results of the studies conducted by Dega (2012); Rankhumise (2014); Kapartzianis (2014); and Pitchimal, et al. (2014). Learner improvement was due to the conceptual change approach used in the intervention programme. Literature gives assurance that the goal of teaching for conceptual change is for learners to adopt more fruitful conceptions while discarding the misconceptions they bring to the learning environment, and that learners are more likely to rid themselves of conceptions that they have evaluated than those that they have not examined at all, as learners did in this study where they negotiated meanings of concepts (Vosniadoou, 1994)..

Figure 9 shows that four learners scored below the mean and only four learners scored above the mean. Of the thirty learners only two learners of the four learners that scored above the mean score obtained 100% in concept mapping. Studies on conceptual change (Pintrich, Marx & Boyle, 1993) revealed that alternative conceptions are sometimes resistant to change. This is one of the reasons why only two learners scored 100% on concept mapping when the rest could not. In the studies by Hewson, Beeth & Thorley, 1998), affective and contextual factors can impede the conceptual change teaching strategy. In this study, although most of the learners showed interest and participated fully during practical activities and discussions, there were few learners that showed no interest in the first lesson, instead they were distracting others. The results were that learners could not link all the concepts well in the concept map activity because they were still holding on to their alternative conceptions that they did not get a chance to evaluate.

Firstly, the researcher expected that learners who fully participated during the intervention lessons would obtain 100% in the assessment activity because the conceptual change teaching strategy requires that learners actively construct meaning of concepts themselves. Secondly, the expectation was that learners that were not so actively involved in the lessons could show improvement in their performance but not obtain 100%. The reason is that although all of them were exposed to the same learning environment but were separated by the quality and richness of their previous knowledge.

The researcher did not expect that only one question (Question 7) in the pre-test could be scored by all the learners. Question 7 required the learner to remember the unit of energy. All the learners who were taught energy using the traditional method that requires the reproduction of knowledge got it right. All the other questions were higher order questions that needed a deeper understanding of the concepts. As a result, most of them could not give the correct responses in the other questions. This study shows that the telling method does not take into account the alternative conceptions that learners bring into the classroom and that alternative conceptions hinder learning.

5.3 To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?

The conceptual change teaching strategy necessitates thorough lesson preparation that takes learners' prior knowledge into consideration. Learners 'prior knowledge can be detected by means of a pre-test. Learners' pre-conceptions are used in lesson planning. Lessons are designed such that learners' pre-conceptions are made explicit and challenged openly in order to create a cognitive conflict using an exposing event (Chinn & Brewer,1993). In this study predictions about gravitational potential energy, kinetic energy and mechanical energy were used. For close monitoring and confidence building learners in this study presented their predictions in groups

It is during the lesson that alternative conceptions are restructured as they hinder conceptual change. In the study, the conceptual change teaching strategy made the intervention lessons to be more interesting and engaging to the learners although there were minimal distractions in the first lesson. Learners were engaged from the beginning of the lesson to the end. Learners thought about each and every concept they were taught. Learners were able to do so because they were active in the construction of meaning of concepts themselves (Bruning, Royce & Dennison, 1995; Pressley, Harris & Marks):

> *If we can learn using computers every day, I can understand all topics better.* [Group 5, Learner 6]
>
> *I went back and forth checking the values for gravitational potential energy, kinetic energy and mechanical energy and that helped me understand the conservation of mechanical energy better.* [Group 3, Learner 3]

Learners understood the concepts correctly because they were active in their learning through doing practical investigations where they determined the dependent and independent variables; collected data in the form of tables; drew graphs; and drew conclusions from graphs drawn. When collecting the correct data for the tables, choosing the dependent and independent variables, and constructing graphs a lot of reasoning.is required. What is important in this exercise is that the learner is active in the construction of this knowledge. The learner gains a deeper understanding of concepts, can see the relationship between concepts and can use the concepts in different contexts as given below:

> *The collected data on the table showed me trends that if either mass or height increases, Gravitational Potential Energy will also increase.* [Group 2, Learner 5]
>
> *The practical activity on Kinetic Energy improved my understanding of the concept* [Group 1, Learner 3]

The PhET simulations also helped the learners in constructing meaning at their own pace because learners did the simulation activities over and over again until concepts at hand made sense to them.

> I went back and forth checking the values for Gravitational Potential Energy, Kinetic Energy and Mechanical Energy and that helped me understand the Conservation of Mechanical Energy better. [Group 3, Learner 3]

Computer simulations are effective in fostering conceptual change as witnessed in several studies (Zietsman & Hewson 1996; White & Horwitz, 1988; McDermott, 1990; Gorsky & Finegold, 1992).

Learners that could not make sense of concepts taught had an option of asking for clarification where they did not understand, not only from their teacher but from their group members and their classmates as well. The classroom environment allowed learners to say what they thought about the topic at hand freely, without the fear of being judged by others. Studies (Brown, Collins & Duguid, 1989; Rogoff, 1990) show that when the social climate of learning is granted centre stage learners both polish their own meanings and help others find meaning Thus, conceptual change is also influenced by social and contextual factors (. Hewson, Beeth & Thorley, 1998).

The implementation of the conceptual change approach requires thorough preparation of lessons to be taught. Firstly, thorough preparation is required in terms of time management as it is time consuming. For example, each lesson was two hours long although that time was exceeded by an hour. Secondly, to support conceptual change, resources are of paramount importance in supporting conceptual change.

An hour was added to the first lesson that was about gravitational potential energy and which learners found most challenging. I did not expect gravitational potential energy to be the most challenging concept. The gravitational potential energy concept challenged learners because firstly, they believe that objects have energy only when they are in a state of motion. Secondly, learners know the formula for potential energy but could not use it to help them understand the meaning of gravitational potential energy. To them, a formula is only used for computing and is otherwise meaningless. Thirdly, most learners did not understand that height was measured relative to a reference point. Fourthly, some learners thought the following concepts carried the same meaning: [gravitational potential energy and gravitational force], as displayed in the following learners' statements:

> *Gravitational force depends on mass and height.* [FG_3L_1]
>
> *The higher the object is from the reference point, the stronger the gravitational force.* [FG_5L_5]

The above unexpected results indicate that for an improvement in the teaching of the Principle of Conservation of Mechanical Energy more time should be allocated for the teaching of the Gravitational Potential Energy concept. All this boils down to a thorough preparation of the lesson on gravitational potential energy which will include an exposing event that will address these alternative conceptions. Once this topic is mastered then it becomes less challenging to teach the next concepts which are kinetic energy and mechanical energy because learners already know how to tackle an abstract, quantitative concept.

Resources chosen should enhance conceptual change and be interesting to the learner. Practical investigations helped the learner to think about the concept at hand and make sense of it by using the hands and the mind as this learner attests to that in the following statement:

> *Being hands on using physical quantities like mass and height in order to determine Gravitational Potential Energy helped me understand Gravitational Potential Energy better.* *[Group 3, Learner 4]*

Learners are living in the 21st century, a technologically advanced age, and hence the use of computer simulations to promote conceptual change. Not only do computer simulations help the learners to restructure their pre-conceptions, it also arouses their interest in the topic and in Science at large.

> *If we can learn using computers every day, I can understand all topics better.* [Group 5. Learner 6]

The conceptual change lesson can be characterised as lengthy owing to factors like negotiation for the acceptable conceptions. Teachers and learners have to engage in discussions and debates. In one hand, the facilitation skills of the teacher have to be sharpened. On the other hand, the evaluation, debating and discussion skills should also be polished in order to influence conceptual change. Choosing a genuine exposing event helps in exposing the learner's alternative conceptions that hinder conceptual change.

Linking the concepts taught with real life examples is the last nail that helps the learner to understand the significance of concepts in real life and in Science in general. The significance of a concept in real life arouses interest about what happens around us and in Science in general.

If I were to do these intervention lesson again, I would ensure that there are no learners who dominate others during the negotiation for an acceptable conception. I would also ensure that there are more real life examples than their pictures. I would also involve learners in collecting real life examples. Lastly, I would ensure that no more than two learners share a computer.

Although this group of learners was correct, but were not expected to give formulae to support their predictions as given by the group below:

> FG2L5: Our predictions about gravitational potential energy was that as the mass of an object increases, gravitational potential energy will also increase.

5.4 What were learners' perception of the conceptual change approach?

At the beginning of all the three lessons learners were asked by the teacher to make predictions related to the concepts at hand. In the first lesson, 4 out of 5 predictions were incorrect and that suggests the type and extensiveness of pre-conceptions that learners had about gravitational potential energy before the intervention.

An exposing event tested their beliefs and had to confront them. This is where doubt and unhappiness emerged from the learners.

> *We became unhappy about our prediction on mechanical energy after exploring simulations on mechanical energy.* [$FG_2L_4T_{71}$]

The energy concept is not new to the Grade 10 learners. It is taught in Grade 8. Also, they did not come across mathematical concepts for the first time where formulae were to be used. The meaning behind the formulae was explained to them in previous chapters and Grades. At the beginning of all the intervention lessons learners were expected to use formulae to help them make predictions but did not.

> … *we did not relate gravitational potential energy and height or mass. We related the force of gravity with mass and height.* [$FG_3L_1T_{107}$]

(Feynman, 1963 & Warren, 1982) suggest that since energy is an abstract concept, when it is introduced to learners, the idea of energy should be treated as a numerical quantity.

The conceptions that learners had were tested and could not solve the problem at hand. Studies on conceptual change show that at this stage, learners become dissatisfied with their conception (Posner, Strike, Hewson & Gertzog, 1982; Nussbaum & Norvick, 1982) and in other studies dissatisfaction is referred to as cognitive conflict (Chan, Burtis, & Bereiter, 1997; Duit & Treagust 2003). In this study: unhappiness, doubt and inability to meet expectations led to learner dissatisfaction with the existing conceptions.

Not all the learners either took the testing of their hypotheses well or respected the views of others. These learners could not learn well any further. These are the learners in statistical analysis who were resilient in discarding or restructuring their existing conceptions. Their resilience was evident in their concept map scores because not all the learners could link all the concepts in the concept maps well. This study reveals that conceptual change provides more value when it is an all-inclusive, holistic teaching approach that is influenced by the different conceptual change perspectives (see section 2.2.2). There interaction between learners or between the learner and the teacher in the learning process (social perspective) although there were few learners that could not explicitly explain their beliefs and as a result conceptual change could not be promoted well.

Motivation and interest arousal are affective factors that promote conceptual change. Teaching is less mentioned by learners as being helpful in their conceptual understanding. This suggests that learners learn better when they construct knowledge themselves. Mainly they need hands-on activities to support learning. Learners knew what all the mechanical energy concepts meant through visualisation and using their minds and this is another important condition for conceptual change, intelligibility; and it was met.

Teaching is only used for scaffolding. Teaching in this study is in the form of a demonstration after which the demonstration is used when learners revisit their responses to the questions posed before the demonstration to check if they were the same as the answers coming from the observations of the demonstration. This exercise promotes cognitive accommodation or restructuring of the learner pre-conceptions.

The same concepts were found to be plausible. Learners defined concepts using formulae; the same formulae were used to solve problems during calculations; and used to link concepts in concept maps.

Other than using words I could define energy concepts using formulae. [$FG_4L_3T_{151}$]

At this stage of conceptual change learners were able to apply knowledge gained in different contexts. Utterances of learners were also noted during the intervention

When the velocity of an object increases or decreases, kinetic energy changes. [Group 5, Learner 2]

This utterance suggests that learners believe that the kinetic energy concept is true because it remains so even when applied in a different context.

Real life examples at the end of the lesson made learners to feel this way:

I feel more confident. I think I can solve any problem on the Principle of Conservation of Mechanical Energy. [$FG_3L_1T_{120}$]

Confidence is a state of being certain that a chosen course of action is most effective. This suggests that at this stage, learners are happy with their conceptions on mechanical energy because they can explain incidences beyond the classroom. Learners feel confident because the gap between their pre-conceptions and the pre-determined, scientific conceptions is closed. All it signifies is that conceptual change has been effected

5.5 Conclusion

This chapter discussed the results of the study. These were the results from the pre-test and were presented in this part to be used in planning for effective lessons during the intervention. The focus group interviews data and the individual-based data from the concept maps were independently analysed using the framework thematic analysis and statistics respectively to categorize the students' post intervention conceptions.

In addition, the conceptual change teaching approach was designed to change learners' alternative conceptions in the concepts of mechanical energy. A significant difference after the intervention on the concept map scores were obtained. Moreover, the mean score was found to be greater in the concept maps than in the pre-test. Both quantitative and qualitative results showed that the conceptual change teaching strategy was more effective in helping learners discard alternative conceptions and accept scientific ones.

The scope, findings, recommendations, limitations, suggestions for further areas of research and concluding remarks are discussed in the next chapter

CHAPTER 6
CONCLUSION

6.1 Introduction

In the previous chapter a discussion of the main findings of the research was done. The main goal of the study was to investigate the impact of the conceptual change approach in the teaching of the Principle of Conservation of Mechanical Energy in Grade 10 Physical Sciences in school X, in the Eastern Cape. This concluding chapter gives an overview of the scope of the study by presenting an impression of what the study is about; the literature review employed; the methodology; findings and discussions summarised. This chapter further provides a summary of the main findings of the study by linking these to the research questions. The implications of the study are explored, and a way forward offered in terms of recommendations. The limitations of the study are presented for further research in the field.

6.2 Overview of the scope of the thesis

6.2.1 The introduction chapter

The introductory chapter provides the rationale of the study by offering the background of the study. Performance in Physics at the National, Provincial and School level is examined. The results showed that learners in the past four years obtained the lowest scores in Mechanics in the Physics Examination Papers. The Principle of Conservation of Mechanical Energy falls under the Mechanics' section in Physics and runs across topics like Vertical Projectile Motion, and Work, Energy and Power.

This chapter also proffers the context of the study as it has an impact on learner performance. It also provides the school location, feeder schools, the socio-economic aspect of learners, the teacher profile, learner-teacher ratio, the current Physical Sciences curriculum followed, learner performance in the subject and in the topic in particular.

The state of Science Education in South Africa is also viewed. Reports from the World Economic Forum's Global Information Technology and the Department of Basic Education paint a gloomy picture of the state of Science Education in South Africa.

Big strides were taken to improve learner performance in Physical Sciences by the Department of Basic Education in partnership with stakeholders like some South African Universities, Private Companies and Agencies. They focussed on teacher development, increase in learner participation, arousal of interest in Physical Science from an early age and the repackaging of the curriculum.

Chapter one also presents the research problem which with the main research question and the research sub-questions could be answered. The significance of the study is offered, not forgetting the limitations of the study. The chapter closes with the layout of the structure of the thesis. Chapter 1 covers the rationale of the study; chapter 2, literature review. Methodology is presented in Chapter 3; Chapters 4 and 5 submits the findings and discussions respectively. Chapter 6 draws the conclusion and makes recommendations for further study in the field. Lastly, Chapter 7 proffers a list of all in-text reference used using the 6th edition of the APA reference system.

6.2.2 Literature review

In chapter two, the theoretical framework in which the study is situated is discussed in detail. In relation to the problem investigated, literature review on constructivism and conceptual change theories are highlighted (see Sections 2.2.1 & 2.2.2) at the beginning of the chapter. Constructivism on one hand puts more emphasis on the fact that a learner will understand a concept better if the learner is active in the construction of meaning of that concept, not forgetting the previous knowledge that the learner brings into a classroom which has an influence on how the learner constructs meaning. On the other hand, the conceptual change theory goes on further to give the details of the stages that the learner should pass through in order for the correct meaning of concepts to be constructed. These stages are: dissatisfaction, intelligibility, plausibility and fruitfulness. Other aspects like learner motivation and interest arousal also play a pivotal role in the conceptual change approach today (see Section .2.2.5)

The second section of literature review focussed on how best energy concepts can be taught (see Section 2.2.3). The teacher's understanding that the energy concept is a numerical quantity, an abstract mathematical concept and therefore teaching the concept should start with the correct scientific definition before the meaning is lost or confused. Next, the way in which the study fits in international and national Physics

Education is also explored (see Section 2.2.4). The last section of literature review gives account of the significance of the topic under study (see Section 2.2.5).

6.2.3 Methodology

In chapter three the methodology used in collecting the data is described. The study employed the mixed methods, i.e. the qualitative and the quantitative research methods as a tool to conduct an in-depth investigation of the conceptual change approach in the teaching of the Principle of Conservation of Mechanical Energy.

The research sample consisted of 30 grade 10 Physical Sciences learners of school X in the Eastern Cape. The thirty learners were purposely selected to take part in the study and were later on divided into five focus groups of six learners each for the interview (See sections 3.3 & 3.4).

The study employed a number of different data collection instruments including the pre-test, the concept map and the interview schedule. Firstly, the pre-test was used to report on the learners' prior knowledge on the Principle of Conservation of Mechanical Energy and help in designing the lesson plans for the intervention programme. Secondly, three lessons on the Principle of Conservation of Mechanical Energy, using the conceptual change approach were prepared and taught in the intervention programme. Thirdly, concept maps were used to determine if there was an improvement in the learners' conceptual knowledge on the topic after the conceptual change lessons. Lastly, the interview schedule was employed in focus group interviews to check the learners' perception of the conceptual change approach. The experts and the pilot study were used ensure the validity and reliability of the research instruments.

The quantitative data analysis method was used for the pre-test and the concept map, and the thematic framework and coding were used to qualitatively analyse the data from interviews (See section 3.5). Statistical analysis was used to analyse the test and concept maps scores. The measure of central tendency on test scores and concept maps was used to statistically describe data using the mean, the mode and the median for the sample. In addition, data was statistically described using the histogram. To infer statistically if the conceptual change strategy made any significant difference in learners' test scores after the intervention, standard deviation and variance were used.

6.2.4 Results

In chapter four, the results based on the quantitative and qualitative data are presented and analysed. The pre-test, concept map and the interview schedule were, respectively analysed and presented. The findings were to answer the four research sub-questions. The scores of the pre-test were used to answer the first research sub-question. The mean score in the pre-test was 6,9 (34,5%) and the scores, in general, clustered between 15% and 45%. These scores did not only display the poor performance of learners in the pre-test, but also the extensiveness of the learners' pre-conceptions on the Principle of Conservation of Mechanical Energy.

The conceptual change lessons were to answer the second research sub-question. The field notes with thick descriptions of what happened during intensive teaching painted a picture of all the nitty grits of those lessons. Learners were actively involved in testing their pre-conceptions and their peers' conceptions too. Practical activities helped them in the process of voluntarily discarding alterative conceptions and accepting the scientifically correct ones. The concept maps answered the third research sub-question in that the way in which the learners wrote those concept maps portrayed an improvement and better understanding of almost all the concepts under the topic.

The focus group interviews answered the fourth research sub-question. The responses that learners gave during the interviews depicted what they perceived about the conceptual change teaching strategy. It rose their interest and unknowingly they found themselves being responsible for their learning. Computer simulations and practical investigations which made learners to hypothesise, conduct investigations about concepts they did not scientifically understand, collect data, analyse it and draw conclusions made them not to only understand concepts better but to confidently use that knowledge in unfamiliar contexts because they have observed Science in action.

6.2.5 Discussion

In general, the number of alternative conceptions were more intensive before the intervention lessons. However, after the intensive intervention instruction, a significant difference was obtained. This means that alternative conceptions decreased in intensiveness while conceptual knowledge was found greater after the intervention.

Therefore, based on the findings of this study, it could be confirmed that the teaching of the Principle of Conservation of Mechanical Energy concepts is more effective with the use of the conceptual change teaching strategy compared to using conventional teaching methods. The knowledge construction and conceptual changes that occurred during and after the intervention process are further confirmed by the statistical analysis of the pre-test and concept map results as discussed in section 5.2. The large value of the mean (80,42 %) after the intervention shows the effectiveness of the intervention in accomplishing conceptual change

From the results of the study, two instructional implications can be drawn. Firstly, to overcome students' misconceptions in Science, the conceptual change teaching strategy can be used as an effective tool. However, it should be noted that despite teaching using the conceptual change approach, a number of misconceptions still persisted. Chin and Brewer (1983) explained that it is very difficult to eliminate students' misconceptions completely. Science teachers should therefore be encouraged to use conceptual change in teaching abstract concepts.

6.3 Major findings of the study

6.3.1 (i) What are learners' initial understanding of the Principle of Conservation of Mechanical Energy?

The first research question investigated the learners' prior knowledge on the Principle of Conservation of Mechanical Energy before the intervention so that alternative conceptions could be identified and corrected in the conceptual change intervention lessons. To answer the first research question, the results of the pre-test were presented and analysed. The study came up with the following findings:

Alternative conceptions identified were on: Gravitational Potential Energy, Kinetic Energy and the Principle of Conservation of Mechanical Energy.

The statistical analysis conducted on the pre-test scores revealed the mean of 34,5% (See Table 6). The pre-test mean score on some other studies on conceptual change (Kaperzianis,2014 & Rankhumise,2014) were 34,87 and 32,4 respectively and were not much different from the mean obtained in this study. A mean of 34,5% is low.

6.3.2 What was learners' understanding of the Principle of Conservation of Mechanical Energy after the conceptual change lesson?

The third research question was about the learners' understanding of the principle of conservation of mechanical energy after the conceptual change lessons. The main findings from the scores of the learners' concept maps were that most of the learners discarded their alternative conceptions on the Principle of Conservation of Mechanical Energy and accepted the correct scientific meaning of concepts in the topic taught

6.3.3 To what extent can a conceptual change framework be used to improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy?

The second research question which was about how conceptual change can improve the conceptual development of Grade 10 learners on the Principle of Conservation of Mechanical Energy. The results extracted from thick descriptions showed that by engaging learners in a variety of practical activities, learners are enabled to claim their rightful place of playing a central role in the learning of correct scientific concepts on the topic. Teaching using the conceptual change approach made learners not only to think about the concepts they were learning but to make sense of the meaning of concepts, how they relate to one another and how to use these concepts in unfamiliar contexts but still maintain their meaning. The effectiveness of the intervention was also perpetuated by the interest and motivation that the teaching strategy arose among learners: engagement in discussions and voting for processes and procedures that made concepts to be understood better.

6.3.4. What were learners' perception of the conceptual change approach?

The fourth research question was about how learners perceive the conceptual change teaching approach. The findings from the interview data showed that learners did not understand most of the concepts when the intervention lessons started but with the use of the conceptual change teaching strategy, learners could find out on their own what they know and what they do not know. With the help of other learners, learners could scientifically understand the meaning of concepts correctly. Confidence was built and learners could learn about these concepts even in unfamiliar contexts.

6.4 Implication of the study

Hewson (1992) reports that it is possible to think about conceptual change entering Science Education in at least four ways. These four implications of conceptual change are: learning Science, teaching Science, learning how to teach Science, and teaching how to teach Science and will be used in this study.

6.4.1 Learning Science

As mentioned above, the research literature has shown that learners come to their Science classrooms with a range of different conceptions of the natural world surrounding them (Duit, 1991). These conceptions vary greatly with respect to such characteristics as clarity, breadth, coherence, ambiguity, and tenacity. In particular, many of these conceptions are at variance with the currently accepted scientific view. The significance of this research lies in the fact that these are the ideas that learners use when they are introduced to normal scientific content. Thus, their learning of this new content is influenced by their current ideas, in ways that may hinder or may help their learning. It therefore is useful to think of learning the desired outcomes as a process of conceptual change, including both extension and exchange.

As noted in the study, intervention is therefore of paramount importance. Proper planning that has taken into consideration learners' preconceptions is a pre-requisite for a successful intervention. It is the preconceptions that hinder learning. The intervention programme serves as a platform where learners test their preconceptions for intelligibility, plausibility and fruitfulness and learners can be able to do so if the teacher challenges learners by presenting an exposing event that will make learners think about the conceptions that they still hold on to. Learners will restructure their conceptual knowledge by actively constructing meaning of concepts under study through social engagement with their peers and the Science teacher. The key idea is to ensure that learners reject their alternative conceptions and accept the scientific ones. Conceptual change ensures learners' interest and motivation in Physics and Physical Sciences in general is aroused and consequently that positively affects learner performance. The results of this study show that learner performance improved drastically after exposure to the conceptual change teaching approach in the intervention programme.

6.4.2 Teaching Science

Existing approaches to the study of energy clearly require examination. Teaching practises apparently leave many students with little ability to use the concept of energy as a descriptive or analytic tool. Teaching energy, an abstract concept, requires a teaching method that will clear alternative conceptions so that scientific concepts can be learnt correctly. Knowledge of alternative conceptions can help define both the starting point of relevant instruction and its eventual outcome. Teacher preparation is crucial when the conceptual change approach is to be used. Noted in the intervention programme were teaching materials that enhance learning and could be incorporated into individual teacher's programs. For future research, instead of using practical investigations and interactive simulations as tools that drive the conceptual change approach, different tools can be used. Bridges from every day to scientific conceptions need to be identified, elaborated, embodied in teaching materials, and tested for instructional utility. Some change in the style of teaching to some extent, I believe, will lead to a significant improvement in learner performance in Mechanics and the significant increase in the choice of Physical Science in institutions of higher learning by girls in particular. South Africa needs more scientists and professionals in Science and Technology than ever.

6.4.3 Learning how to Teach Science

There are different aspects considered in conceptual change teaching. The first aspect is the existing conceptions and reasons why they are held. The second aspect is metacognition wherein learners are encouraged or able to “step back” from one or more ideas held by themselves or others in order to think about them and express an opinion about them. The other aspect is the classroom climate where an attitude of respect by both teacher and learners for the ideas of others, even when they are contradictory is looked into. Next, is the status change where the teacher uses strategies designed to help learners lower the status of existing, problematic knowledge, and raise the status of other, competing ideas. What needs to be checked is whether there are other application sites where the new conception can be used. Next, is the evidence that students’ learning outcomes are based, in part, on an explicit consideration of their prior knowledge. All these aspects were considered in the intervention programme so that learner performance in the Principle of Conservation of Mechanical Energy can improve.

6.4.4 Teaching how to Teach Science

It would be unreasonable to expect aspiring or new entrants into the teaching profession to implement instructional strategies with which they were unfamiliar as was the case with the new South African science curriculum. It seems important that pre-service Science teachers be exposed in their training institutions to new instructional approaches that they would need when they commence their instructional practices.

The disjuncture between the efforts in science method courses at tertiary institutions and classroom practice is a well-known phenomenon. Often pre-service teachers find it difficult to see the connection between the generally theoretical method courses and actual classroom situations. My experience in the study has however, shown that this anomaly could be ameliorated if pre-service teachers are given opportunities to:

- Develop dedicated resource material, lesson plans, structured argumentation writing frameworks and time-on-task activities aligned to CAPS pace setters.
- Plan, design and practice individual and co-operative presentations during their course of study.
- Work under the supervision of supervisors as well as mentor teachers prior to beginning science teachers reporting at schools for teaching practice, on the methodological approaches that they would be implementing.
- Become sufficiently schooled in the use of argumentation instructional skills prior to the teaching practice.
- Visit with school management to assess the latter's willingness to accommodate the needs of pre-service science teachers to implement argumentation methodology.
- Work in a functional rather than a dysfunctional school so as to enable them to practise their teaching skills.

I would argue that, just as learners develop conceptions of everyday events, prospective teachers can similarly be expected to develop conceptions of teaching based on their own experiences as students in many different classrooms, from courses in teacher education programs, and as student teachers. Thus, they can be expected to build conceptual structures in which they incorporate classroom events, instructional concepts, socially accepted behaviours, and explanatory patterns. These structures include, possibly implicitly on the one hand, their rationale for teaching and their view of knowledge, learning, and science, their disciplinary knowledge, and on the other hand the ways in which they teach.

6.5 Limitations of the study

It is worth mentioning that this is a small scale study, in one Physical Sciences Grade 10 class in a particular school (See section 1.2.2) of which it can be argued that the findings of the research study may not be generalised to other schools. However, the study can be used by other teachers as a tool to research their own practices so as to improve, be abreast with and adapt to the current and contemporary trends in the teaching and learning environment. The intention of the study is to find out if the conceptual change teaching approach will improve learner performance in the Principle of Conservation of Mechanical Energy taught in Grade 10.

The scope of the study is limited only to the concepts relating to the Principle of Conservation of Mechanical Energy and are a build up to other concepts in Mechanics like Vertical Projectile Motion as well as Work, Energy and Power. Moreover, these concepts are learnt in English, the language of learning and teaching. English is a Second Language to school X learners. English limits learners when explaining, defining and trying to understand concepts they try to learn. Their level of understanding and being conversant in English are two totally different aspects. There are learners who can express themselves better in English than others during discussions and presentations. Language plays a pivotal role in knowledge construction. In addition, Grade 10 learners are from different feeder schools and different backgrounds in school X, and that impacts negatively in their learning because they bring into the classroom a variety of pre-conceptions about the topic to be taught.

In addition, a limited number of tests, which are a pre-test and a concept map were used as research instruments for tracing the effectiveness of the conceptual change teaching strategy and that limited the study.

Only Grade 10 learners could be used in the study although the concepts relating to the Principle of Conservation of Mechanical Energy are carried over to Grade 12. Grade 12 learners, who could have benefitted in the teaching of the topic, could not participate in the study because they were preparing for the end of the year examination.

6.6 Recommendations for future research

Based on the findings of this study, the following recommendations were forwarded for improving instruction and for further research.

- Teachers of Physics at all levels should emphasize the correct epistemological and ontological categorization of concepts during their teaching.
- This thesis has covered only a selected area of Physics concepts, the concepts of the Principle of Conservation of Mechanical energy in Grade 10. The selection of the topics was largely motivated by the conceptual difficulties of these concepts in the Mechanics Core Knowledge Area. Thus, future research could perform a similar design of the study using different Grades and Physics topics in order to have a more general idea of the categorization of different concepts.
- For a broader research, a bigger sample from clustered schools or schools in the district can be conducted.
- An inclusive multi-perspective conceptual change research that includes epistemological, ontological and affective perspective of students' conceptions should be undertaken in order to have a relevant and improved application of the conceptual change theory in the contemporary times.
- Conceptual change is a complex process, and requires the proper environment and equipment. Therefore, classrooms and/or laboratories must be equipped with the necessary materials and computer equipment.
- Effective conceptual change also requires a great amount of effort from the teachers. For this reason, the experiential training of teachers is more than essential, in order to achieve the long-pursued objective of the replacement of students' misconceptions with scientifically acceptable ones.

6.7. Final conclusions.

This concluding chapter draws on the main themes emerging from the findings and seek to link these to the research questions. Also, the implications for instructional practice for such findings are examined. Finally, the chapter offers some suggestions for the relevant stakeholders.

REFERENCES

Babbie, E. & Monton, J. (2001). *The practice of social research*. Cape Town: - Oxford University Press.

Bell, B. (2005). Pedagogies developed in the learning in science projects and related theses. *International Journal of Science Education. 27(2),* 159–182.

Bliss, & Orgbon, (1989). Tools for exploratory learning. *Journal of Computer Learning. 5,* 37 – 50.

Braun, V. & Clarke, V. (2006). Using thematic analyses in psychology. *Qualitative Research in Psychology, 3:* 77-101

Brooks, J., & Brooks, M. (1993). *The case for the constructivist classrooms*. Alexandria, Va: ASCD.

Brophy, J.E. (1992). Probing the subtleties of subject-matter eaching. *Educational Leadership 9 (7), 4–8.*

Brown, J.S., Collins, A. & Duguid, P. (1989). Situated Cognition and Culture of Learning. *Educational Researcher, 18 (1),* 32 – 42.

Bruning, Royce & Dennison, (1995). *Cognitive psychology and instruction. (2nd ed.).* Englewood Cliffs: Prentice Hall.

Bruning, R.H., Schraw, G.J. & Ronning, R.R. (1999). *Cognitive Psychology and Instruction.* Saddleback River, N.J.: Prentice Hall.

Calik, A. & Coll, (2009). Investigating the effectiveness of an analogy activity in improving students' conceptual change for solution chemistry concepts. *International Journal of Science and Mathematics Education. 7(4),*651 – 676.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: A Bradforde Book. The MIT Press. (1985).

Champagne, Gunstone & Klopfer (1985). Effecting changes in cognitive structures among physics students. In L.H.T. West & A.L. Pine (Eds). *Cognitive structure and conceptual change.* Academic Press.

Chan, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. *Cognition and Instruction, 15(1),* 1–40.

Chi, M.T.H., Slotta, J.D. & Leeuw, N. (1994). From things to process: A Theory of conceptual change for learning science concepts. *Learning and instruction,4,* 27 – 43.

Chi, M. T. H. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In R. Giere

(Ed.), *Cognitive Models of Science: Minnesota Studies in the Philosophy of Science,* (pp. 129–186). University of Minnesota Press: Minneapolis, MN.

Chinn, C. A., & Brewer, W. F. (1993a). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. Review of Educational Research, 63, 1-49

Cobb, P. (1994). Constructivism in mathematics and science education. *Educational Researcher.* 23 (*7*), 4.

Cohen, L., Manion, L. & Morrison, K. (2008). *Research methods in education (6th edition).* London & New York: Routledge.

Cohen, L., Manion, L. & Morrison, K. (2011). Research Methods in Education. *British Journal of Educational Technology, 42(5),* 110-115.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches.* Thousand Oaks: Sage Publications

Creswell, J. W. (2008*). Educational research: Planning, conducting and evaluating quantitative and qualitative research.* Upper Saddle River. N.J. Pearson/ Merrill Prentice Hall.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches (3rd ed.).* Los Angeles. Sage Publications.

Davis, R., Maher, C., Noddings, N. (1990). Introduction: Constructivist views on the teaching and learning of mathematics. In R. Davis, C. Maher, & N. Noddings (Eds.). *Constructivist views on the teaching and learning of mathematics* (pp.7-18). Reston, Va: National Council of Teachers of Mathematics.

Dega, B.G. (2012*). Conceptual change through cognitive perturbation using simulations in electricity and magnetism: a case study in Ambo University, Ethiopia.* (Unpublished masters' thesis). University of South Africa.

Dekkers, P.J.J.M. & Thijs, G.D. (1998). Making productive use of students' initial conceptions in developing the concept fore. *Science Education, 82,* 31-51.

Dewey, J. (1910). *How we think.* Boston: D.C. Health & Company.

diSessa, A. A. (1993). Towards an epistemology of physics. *Cognition and Instruction, 10, (2&3),* 105–225

Department of Basic Education. (2013). *Investigation into the implementation of Maths, Science and Technology Report.* Pretoria, South Africa.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990). Applying the ''Cognitive Conflict'' strategy for conceptual change - Some implications, difficulties, and problems*. Science Education, 74(5),* 555-569

Duit, R. (1987). Research on students' alternative frameworks in science topics, theoretical frameworks, consequences for science teaching. In J. Novak (Ed.) *Proceedings of the International Seminar Misconceptions and Educational Strategies in Science and Mathematics Vol 1* (pp 152 - 162). Ithaca, NY: Cornell University.

Duit, R. (1999). Conceptual change approaches in science education. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 263 – 282). Amsterdam, NL: Pergamon.

Duit, R., & Treagust, D. (2003). Conceptual change: a powerful framework for improving science teaching

Durrheim, K. (2006). Research design. In Research in practice. Edited by Terre Blanche, M., Durrheim, K. & Painter, D. Cape Town: University of Cape Town Press. 33 - 59.

Dyer, C. (1995). *Beginning Research in Psychology: A Practical Guide to Research Methods and Statistics.* Oxford, UK: Blackwell.

Feynman, R. (1963). *The Feynman Lectures on Physics, Vol 1.* New York: Addison Wesley

Fraenkel, R. & Warren, E. (2000*). Educational Research: A Guide to the Process.* New York. Mac Gaus Hill Inc.

Frey, J.H. & Oishi, S.M. (1995). *How to conduct interviews by Telephone and in Person (Survey Kit, Vol 4).* Thousand Oaks: Sage.

Goiordan, A. (1991). The importance of modelling in the teaching and popularization of science. *Impact of Science on Society, 41 (164),* 321 – 338.

Gorsky, P. & Finegold, M. (1992) Using computer simulations to restructure students' conceptions of force. *Journal of Computers in Mathematics and Science Teaching, 11 (2),* 163 – 178.

Green, J.C., Caracelli, V.J., Valerie J. & Graham, W.F. (1989). Towards a conceptual framework for mixed-method evaluation design. Evaluation and Policy Analysis, 11 (3), 255-274

Gyoungho, L. & Taejin, B. (2011). An explanation for the difficulty of loading conceptual change using a counterintuitive demonstration: The Relationship between Cognitive Conflict and Responses. *Res Sci Educ, 42 ,* 943 – 965.

Henning, E., van Ransberg & Smit, B. (2004) *Finding Your Way in Qualitative Research.* Pretoria: Van Schaik Publishers.

Hewson, P.W., Beeth, M.E. & Thorley, N.R. (1998). An appropriate conception of teaching science: A view from studies of science learning. *International Handbook of Science Education, 2,* 199 – 218.

Hewson, P.W. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*, 383 – 396.

Igwebuike, T.B. (2012). Effects of conceptual change pedagogy on achievement by high ability integrated science students on energy concepts. *International Journal of Research Studies in Educational Technology, 2 (1), 3 – 14.*

Jenkins, E. W. (2000). Constructivism in school science education: Powerful model or the most dangerous intellectual tendency. *Science & Education, 9,* 599-610.

Kaboro, P.G., Nguta, C.M. & Okere, M.O. (2015). Effects of teaching using a "dance' analogy on secondary school Physics students' conceptualization of heat concept. *International Journal of Information Research and Review, 2 (10),* 1274 – 1284.

Kapartzianis, A. & Kriek, J. (2014). Conceptual change activities alleviating misconceptions about electric circuits. *Journal of Baltic Science Education, 13(3),* 292 – 315.

Krajck, J.S., Simmons, P.E. & Lunetta, V.N. (1998). A research strategy for the dynamic study of students' conception and problem solving strategies using science software. *Journal of Research in Science Teaching, 25*, 147 – 155.

Kvale, D. (1996). *Interviews.* London: SAGE Publications.

Kuhn, T.S. (1962). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press (2nd edition, 1970).

Li, S.C., Law, N. & Lui, A.K.F. (2006). Cognitive perturbation through dynamic modelling: a pedagogical approach to conceptual change in science. *Journal of Computer Assisted Learning, 22(6),* 405 – 422.

Limon, M. (2001). On the Cognitive Conflict as an Instructional Strategy for Conceptual Changes: A Critical Appraisal. *Learning and Instruction, 36 (4- 5),* 357-380.

Lock, J. (1947). *An essay concerning human understanding.* Dent: London.

Masondo, S. (2016, May 31). Education in South Africa: A system in crisis. *City Press.* P. 1.

Matthews, W.J. (1998). Let's get real: The fallacy of post modernism. *Journal of Theoretical and Philosophical Psychology, 18, 16-33.*

McDermoth, L.C. (1990). A perspective on teacher preparation in physics and other sciences: The need for special science courses for teachers. *The American Journal of Physics, 58,* 734 – 742.

McGregor, S.L.T. (2014). Transdisciplinarity and Conceptual Change. *World Futures: The Journal of New Paradigm Research. 70 (3-4),* 200 – 232.

Mc Millan, J.H. & Schumacher, S. (2001). *Research in education: A conceptual introduction (5th ed.).* New York: Longman

Mc Millan, J.H. & Schumacher, S. (2010). *Research in education: Evidence-based inquiry (7th ed.).* New York: Pearson.

Merriam, S. B. (1998). *Qualitative Research and Case Study: Applications in Education (2nd ed.).* San Francisco: Jersey Bass.

Miles, M. B. and Huberman, A. M. (1994)*. Qualitative data analysis: A resource book of New methods.* Beverly Hills: Sagei

Miller, K.J, Koury, K. A., Fitzgard, G. E.,Hollingsead, C., Mitchem, K., J., Tsai, H., &Park, M. (2009). Concept mapping as a research tool to evaluate conceptual change related to instruction methods. *Journal of the Teacher Education Division of the Council for Exceptional Children*. 32(4), 365-378.

Mistades, V.M. (2009). Concept mapping in Introductory Physics. *Journal of Education and Human Development, 3(1),* 177-185.

Morgan, D.L. (1996). *Focus groups as qualitative research. (2nd ed.).* Thousand Oaks: Sage.

Morse, J.M. (1998). *Nursing Research: The application of qualitative approaches.* London: Chapman and Hall.

Moshman, D. (1982). Exogenous, endogenous and dialectal constructivism. *Developmental* review*, 2 (4*), 371 – 384.

Naylor, S. & Keogh, B. (1999). Constructivism in classroom: Theory into practice*. Journal of Science Teacher Education, 10,* 93-106.

Nola, R. (1998). Constructivism in science and science education: A philosophical critique. In M. Mathews (Ed.) *Constructivism in science education* (pp. 31-59). Dordrecht, The Netherlands: Kluwer.

Novak, J.D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27 (10)*, 937-949.

Nussbaum, J., & Novick, S. (1982). Alternative Frameworks, Conceptual Conflict and Accommodation: Toward a Principled Teaching Strategy. *Instructional Science, 11(3),* 183-200.

Nwankwo, M.C. & Madu, B.C. (2012). Effect of Analogy Teaching approach on Students' Conceptual Change in Physics. *Greener Journal of Educational Research, 4 (4),*119 – 125.

Ogborn, J. (1986). Energy and fuel: the meaning of 'the go of things'. *School Science Review, 68, 30 – 35.*

Ohlsson, S. (2009). Resumption: a possible mechanism for conceptual change and belief revision. *Educational Psychology, 44*, 20 – 40.

Orgill & Bodner, (2004). The analysis of analogy uses in the teaching of introductory quantum theory. Chemistry Education Research and Practice. DOI: 10.1039/CSPR000011D. Retrieved 17 March 2015.

Osborne, R. & Freyberg, P. 1995*. Learning science: The implication of children's science.* Heinemann Education: New Zealand.

Ozkan, G. & Selcuk, G.S. (2013). The use of conceptual change texts as class material in the teaching of 'sound' in Physics. *Asia Pacific Forum on Science Learning and Teaching.14 (1),* 1 – 22.

Papert, S. (1980). *Mind storms: children, computers and powerful ideas.* New York: Basic Books, MLA.

Patton, M.Q. (2002). *Qualitative Research and Evaluation Methods (3rd edition).* Sage Publications: Thousand Oaks.

Piaget, J. (1977). *Equilibration of cognitive structures.* New York. Viking Press.

Piaget, J. (1970). *Logic and psychology (translation, W. Mays),* NY: Basic Books.

Piaget, J. (1968). *On the Development of Memory and Identity (Translation by E. Duckworth).* Worcester, Massachussets: Clarke University Press.

Piaget, J. (1967). *Biologie et connaissance (Biology and knowledge).* Paris: Gallimard.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change*. Review of Educational Research, 63,* 167–199.

Posner, G. J.,Strike, K. A.,Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Prawat, R.S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education, 100 (3)*, 354 – 395.

Presley, M., Harris, K.R. & Marks, M.B. (1992). But good strategy instructors are constructivists! *Educational Psychology Review, 4,* 3 – 31.

Rankhumise, M.P. & Sitwala, N. I. (2014). Using a Bicycle Analogy to Alleviate Students' Alternative Conceptions and Conceptual Difficulties in Electric Circuits. *Mediterranean Journal of Social Sciences, 5(15),* 297 – 302.

Robottom, I. (2004). Constructivism in Environmental Education: Beyond Conceptual Change Theory. *Australian Journal of Environmental Education, 20(2)*, 93-101.

Rogoff, B. (1990). *Apprenticeship in Thinking. Cognitive Development in Social Context.* New York: Oxford University Press.

Roth, W. M. & McGinn, K. M. 1998. Knowing, research, and reporting science education. Lessons from science and technology. *Journal of research in science education, 35(2): 213-235.*

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58(1)*, 136-153.

Şahin, Ç. (2010). *Design, Implementation and Evaluation of the Guided Materials based on the "Enriched 5E Instructional Model" for the Elementary 8th Grade "Force and Motion" Unit* (PhD Thesis). Karadeniz Technical University, Institute of Science, Trabzon, Turkey.

Sayser, N.J. (2014). *Development of an instrument that supports and monitors inclusive cultures, policies and practices in a Western Cape school* (Unpublished master's thesis). University of Western Cape.

Scott, D. & Usher, R. (2011). *Researching Education: Data Methods and Theory in Educational Inquiry. 2nd edition.* London: Continuum.

Scott, P. H.; Asoko, H. M. & Driver, R. H. (1991). *Teaching for conceptual change: A review of strategies.* Retrieved from http://www.phvsics.ohio-state.edu/~jossem/ICPE/C5.htm.

Sexl, U. R. (1981). Understanding energy as a conserved quantity. *Journal of science education, 3, 291-301.*

Stavy, R. (1998). Conceptual development in science education (guest editorial). *International Journal of Science Education, 20 (10),*1151 – 1154.

Strydom, P. (2000). *Discourse and Knowledge: The making of Enlightenment Sociology.* Liverpool: UK. Liverpool University Press

Strike, K., & Posner, G. (1992). A revisionist theory of conceptual change. In R. A. Duschl and R. Hamilton (Eds.), *Philosophy of science, cognitive* *psychology, and educational theory and practice* (pp. 147-176). Albany, NY: SUNY Press.

Suchting, W. (1998). Constructivism deconstructed. In M. Mathews (Ed.) *Constructivism in science education*. Dordrecht, The Netherlands: Kluwer.

Suping, S.M. (2003). *Conceptual Change among Students in Science.* ERIC Clearinghouse for Science, Mathematics and Environmental Education. (ED482723)

Teddie, C. & Tashakkori, A. (2009). *Foundations of Mixed Methods Research: Integrating quantitative and qualitative approaches in the social and behavioural.* Thousand Oaks: Sage.

Thagard, P. (1992). *Conceptual Revolutions.* Princeton N.J.: Princeton University Press.

Tytler, R.W. (1998). Children's conceptions of air pressure: Exploring the nature of conceptual change. *International Journal of Science Education, 20 (8),* 929 – 958.

von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Syntheses, 80*, 121-140.

von Glasersfeld, E. (1995). *Radical Constructivism: A way of knowing and learning*. The Falmer Press

Vosniadou, S. (2008). *International Handbook of Research on Conceptual Change.* New York: Routledge.

Vosniadou, S. 2007). Conceptual Change and Education. *Human Development, 50,* 47 – 49.

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18(1),* 123-183.

Vosniadou, S., & Brewer, W.F. (1992). Mental models of the earth. A study of conceptual change in childhood*. Cognitive Psychology, 24,* 535-585.

Vygotsky, L. (1978*). Mind in society: Development of Higher Psychological Processes.* Cambridge: MA: Harvard University Press.

Warren, J. (1982). The nature of energy. *European Journal of Science, 4 (3),* 295 – 297.

White, B. & Horwiz, P. (1988). A challenge to conceptual change. *Science Education, 77(3),* 293-300.

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008a). PhET: Simulations that enhance learning. Science, 322(5902), 682-683.

Wieman, C. E., Perkins, K. K. & Adams, W. K. (2008b). Oersted Medal Lecture 2007: Interactive simulations for teaching physics: What works, what doesn't, and why. *American Journal of Physics, 76 (4&5),* 393-399.

World Economic Forum (2014) *The Global Competitive Report 2014 - 2015.* Geneva: World Economic Forum.

Yin R. K. (2007). *Case Study research: Design and methods.* New Delhi: Sage.

Zacharia, Z., & Anderson, O. R. (2003). The effects of an interactive computer-based simulation prior to performing a laboratory inquiry-based experiment on students' conceptual understanding of physics*. American Journal of Physics, 71 (6*), 618-629*.*

Zeynel, D. (2015). Anomalies and conflicts in classroom discourse. *Journal in Science Education, 84 (4),* 429 – 444.

Zietsman, A.I. & Hewson, P.W. (1986). Journal of Research in Science Teaching, 23(1), 27 – 39.

Zhou, G. (2010). Conceptual Change in Science: A process of Argumentation. *Euresia Journal of Mathematics, Science & Technology, 6 (2),* 101 – 110.

APPENDICES

Appendices 1: Ethical clearance from University

University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

Background information sheet

Dear Sir/Madam,

My name is Nondumiso Pika, a Masters student in the School for Science and Mathematics Education of the Faculty of Education at the University of the Western Cape. I am conducting research on the teaching of the Principle of Conservation of Mechanical Energy in Grade 10 Physical Sciences in order to explore how the use of the conceptual change approach can improve learner performance in the topic.

Research Title: The teaching of the principle of conservation of mechanical energy using a conceptual change approach

Research question: How can the teaching of the principle of conservation of mechanical energy through conceptual change improve learner conception?

The research participants will comprise thirty Grade 10 Physical Sciences learners. Data collection will be in the form of tests and interviews in the Grade 10 classroom. Participation in this study is voluntary. Participants have the right to withdraw from the research at any stage of the research process without having to give any explanations. Participants are guaranteed utmost confidentiality regarding all information collected from them. Pseudonyms or a system of coding will be used to protect their identity.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely

Researcher: Mrs. Nondumiso Pika
Contact number: 082 747 6291
Email: ndumipika@gmail.com

Supervisor: Prof. Shaheed Hartley
Tel. 021-9592680
Email:shartley@uwc.ac.za

Signature of the researcher: ……………………Date:……………………………

University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

X Senior Secondary School
Stepping Stone Road
Durbanville
7550

The Research Director
Eastern Cape Education Department
Private Bag X 0032
Bisho

Dear ________________

Re: Permission to conduct research at X School

My name is Nondumiso Pika, a Masters student in Science Education in the School of Science and Mathematics Education of the Faculty of Education at the University of the Western Cape. I would like to request your permission to observe learners in the Grade 10 Physical Sciences classroom in one of the secondary schools in Cofimvaba.

I am conducting research on the application of a conceptual change approach to teach the principle of conservation of mechanical energy in Grade 10 Physical Sciences in order to explore the impact of this approach on learner performance. The target group will be the Grade 10 Physical Sciences' learners in the FET phase.

The research will not interfere in any way with the functioning of the school or with learning in the classroom. In addition, participation will be voluntary and so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. Their participation in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than to understand how the application of the conceptual change approach in teaching the Principle of Conservation of Mechanical energy will be used in a grade 10 Physical Science class.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs. Nondumiso Pika
Contact number: 082 747 6291
Email: ndumipika@gmail.com

Supervisor: Prof. Shaheed Hartley
Tel. 021-9592680
Email: shartley@uwc.ac.za

Signature of the researcher…………………Date……………………………

University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

X Secondary School,
P. O. Box 33
Cofimvaba
5380

Dear ________________

Re: Permission to conduct research in your School

My name is Nondumiso Pika a Masters student in Science Education in the School of Science and Mathematics Education of the Faculty of Education at the University of the Western Cape. I am conducting research on the application of a conceptual change approach to teach the principle of conservation of mechanical energy in Grade 10 Physical Sciences in order to explore the impact of this approach on learner performance. The target group will be the Grade 10 Physical Sciences' learners in the FET phase.

I would like to request your permission to interview and test learners in the Grade 10 Physical Sciences classroom as in one of the secondary schools in Cofimvaba.

The research will not interfere in any way with the functioning of the school or with learning in the classroom. In addition, participation will be voluntary and so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. Your participation and that of the learners in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than to understand how the use of tablets enhances literacy development skills in Grade 6 classroom.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs. Nondumiso Pika
Contact number: 082 747 6291
Email: ndumipika@gmail.com

Supervisor: Prof. M.S. Hartley
Tel. 021-9592680
Email: shartley@uwc.ac.za

Signature of the researcher: ………………………Date: ………………………

Appendices 4: Permission letter to the parents

University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

X Primary School,
Stepping Stone Weg,
7550
Durbanville

Dear _________________

Re: Permission for your child's participation in a research

My name is Nondumiso Pika a Masters student in Science Education in the School of Science and Mathematics of the Faculty of Education at the University of the Western Cape. I am conducting research on the application of a conceptual change approach to teach the principle of conservation of mechanical energy in Grade 10 Physical Sciences in order to explore the impact of this approach on learner performance. The target group will be the Grade 10 Physical Sciences' learners in the FET phase.

I would like to request your permission to interview and test learners in the Grade 10 Physical Sciences classroom as in one of the secondary schools in Cofimvaba.

The research will not disrupt the class schedules or teaching and learning in the classroom. In addition, participation will be voluntary, so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. The identity of the learners in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than to understand how the use of the conceptual change approach to improve performance in the understanding of scientific concepts and improvement in performance of learners in the Principle of Conservation of Mechanical Energy in Physical Sciences in the Grade 10 classroom. Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs. Nondumiso Pika
Contact number: 082 747 6291
Email: ndumipika@gmail.com

Supervisor: Prof. M.S. Hartley
Tel. 021-9592680
Email: shartley@uwc.ac.za

Signature of the researcher: ………………………Date:……………………………

University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

I agree to be part of the study and I am aware that my participation in this study is voluntary. If, for any reason, I wish to stop being part of the study, I may do so without having to give an explanation. I understand the intent and purpose of this study.

I am aware the data will be used for a Master's thesis and a research paper. I have the right to review, comment on, and/or withdraw information prior to the paper's submission. The data gathered in this study are confidential and anonymous with respect to my personal identity, unless I specify or indicate otherwise. In the case of classroom observations and interviews, I have been promised that my personal identity and that of the school will be protected, and that my duties will not be disrupted by the researcher.

I have read and understood the above information. I give my consent to participate in the study.

__________________ __________________

Participant's signature Date

__________________ __________________

Researcher's signature Date

Appendices 6: Parents Informed consent form

I agree that my son/daughter……………………………………………(name) can be part of the study and I am aware that his/her participation in this study is voluntary. If, for any reason, he/she wishes to stop being part of the study, I may do so without having to give an explanation. I understand the intent and purpose of this study.

I am aware the data will be used for a Master's thesis and a research paper. I have the right to review, comment on, and/or withdraw information prior to the paper's submission. The data gathered in this study are confidential and anonymous with respect to my son/daughter personal identity, unless I specify or indicate otherwise. In the case of classroom observations and interviews, I have been promised that my son's/ daughter 's personal identity and that of the school will be protected, and that the normal classroom activities will not be disrupted by the researcher.

I have read and understood the above information. I give my consent for my son/daughter to participate in the study.

____________________ ____________________

Participant's signature Date

____________________ ____________________

Researcher's signature Date

PRE-TEST ON ENERGY CONCEPTS MAY 2016

MARKS: 20 DURATION: 40min

1. Energy exists in two states. They are:
   A. Friction and reflection
   B. Potential and kinetic
   C. Solar and nuclear
   D. Chemical and thermal (2)

2. What is potential energy?
   A. The energy of motion
   B. Stored energy
   C. Atomic energy
   D. Nuclear energy (2)

3. What happens to a ball when it is dropped?
   A. Kinetic energy becomes potential energy
   B. Potential energy changes to kinetic energy
   C. Potential and kinetic energy stay the same
   D. Kinetic energy remains the same (2)

4. An apple hanging from a branch has potential energy because:
   A. It is not moving
   B. Of its position off the ground
   C. It is ripe
   D. It is still green (2)

5. An apple falling from a tree
   A. Is losing potential energy as it nears the ground
   B. Is gaining kinetic energy as it falls
   C. Is losing kinetic energy as it falls
   D. Is gaining potential energy as it moves away from the tree (2)

3. What happens to a ball when it is dropped?

6. The quantity $1/2\ mv^2$ is

A. Kinetic energy becomes potential energy

A. The potential energy of the object.

B. The work done on the object by the force.

C. The power supplied to the object by the force.

D. The kinetic energy of the object (2)

7. The unit of energy is the

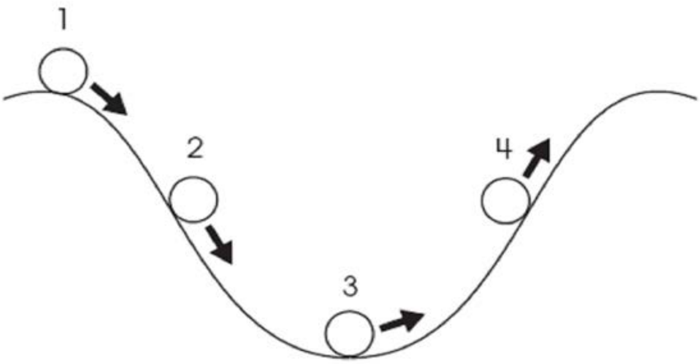
A. Newton

B. Joule

C. Meter

D. Litre (2)

8. Use the following information and diagram to answer question 8.



(2)

A ball is released from rest at position 1. The diagram shows the ball in four positions as it rolls along a track from left to right. In which position does the ball have its minimum gravitational potential energy and maximum kinetic energy?

A. 1

B. 2

C. 3

D. 4h

9. A bobsled and rider have 100 kg of mass combined. They reach the bottom of the hill having attained a speed of 72 km/hr. Assuming all of their gravitational potential energy was converted to kinetic energy, how high was the hill?

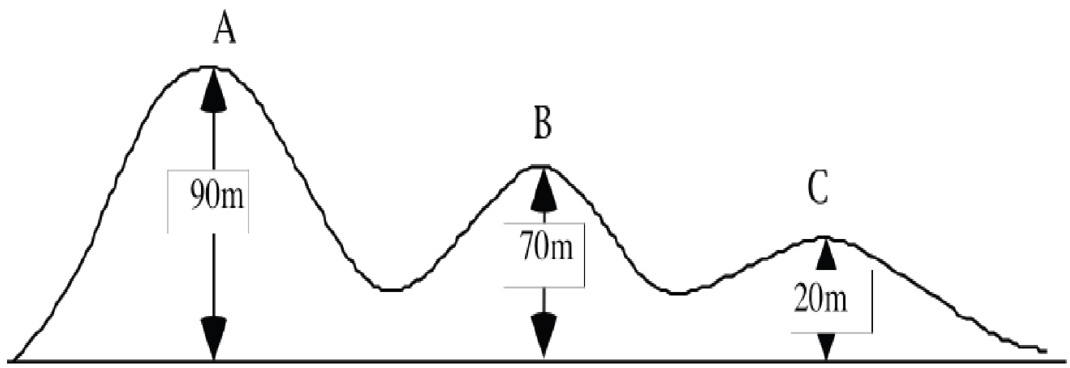
A. 204 m

B. 42

C. 20.4 m

D. 264.2 m

10. A roller coaster is at the top of hill A and is moving at 15 m/s. What will be its speed at the top of hill C?



A. 8 m/s.

B. 17 m/s.

C. 37 m/s.

D. 40 m/s. (2)

MEMORANDUM

1. B √√
2. B √√
3. B√√
4. B √√
5. B √√
6. D√√
7. B √√
8. C√√
9. C √√
10. C √√ [2 X 10 = 20]

Appendices 8: Copy of lesson plan 1

Subject: Physical Science	Grade: 10
Lesson plan: 01	Topic: Gravitational Potential Energy
Duration of the lesson: 2 hours	Date: ………………………………

Content: Mechanics				
Context: Energy and principle of conservation of mechanical energy				
Activities	Presentations; discussions; evaluations	Practical investigation; drawing; interpretation of graphs & reflections.	Presentations; discussions; calculations	Discussions
Conditions for conceptual change:	Dissatisfaction: In groups: Learners make a hypothesis based on the quantities on which the magnitude of the gravitational potential energy depends. Learners discuss the basis of their predictions. Using the formula and definition of gravitational potential energy the teacher evaluates the hypothesis	Intelligibility: In groups: Learners do a practical investigation using the correct hypothesis based on the formula. In pairs: Learners draw graphs that relate the independent and the dependent variable using the data collected during the investigation. Learners interpret the graph and draw conclusions that are compared with the hypothesis.	Plausibility: In groups: Learners define the following concepts: energy; work; force (gravitational); distance & height. Learners discuss the relationship between energy and work using the information above. Individually: Learners	Fruitfulness: In groups: Learners choose examples of images of gravitational potential energy found in real life.

	common to more than one group. In pairs: Learners evaluate the remaining groups' hypotheses using the same method.		calculate gravitational potential energy using the formula $E_p = m.g.h$ in different contexts.	
Teaching method and approach	Inquiry, cooperative learning, direct instruction			
Assessment strategies	Self, peer, group, teacher			
Forms of assessment	Classwork, homework, presentation, group discussion			
Resources	Textbook, internet, chart			
Teacher reflections	Evaluating learners' responses. Providing feedback on their responses Provision of additional support.			

Appendices 9: Copy of lesson plan 2

LESSON PLAN: PHYSICAL SCIENCE

Subject: Physical Science	Grade: 10
Lesson plan: 02	Topic: Kinetic Energy
Duration of the lesson: 2 hours	Date: …………………

Content: Mechanics				
Context: Energy and principle of conservation of mechanical energy				
Activities	Presentations; discussions; demonstration; evaluation & reflection	Practical investigation; writing of a conclusion.	Presentations; discussions; calculations using the formula & observations	Discussions
Conditions for conceptual change:	Dissatisfaction: In groups: Learners discuss the following questions and present their answers to the whole class: If two objects with similar mass are dropped from different heights, which one will have the higher velocity as it hits the floor?	Intelligibility: In groups: Learners do a practical investigation to determine the kinetic energy of marbles that have different masses and velocities by observing the dents formed as the marbles fall onto the plasticine.	Plausibility: Individually: Learners do calculations based on kinetic energy using: $E_k = ½ mv^2$ in different contexts. In groups:	Fruitfulness: In groups: Pictures of kinetic energy in use in the internet expose learners to real life application of kinetic energy.

	Learners discuss the basis of their answers. Demonstration: The teacher does an experimental demonstration that answers the questions above. In groups: Learners reflect on and evaluate their answers based on the demonstration above.	In pairs: Learners draw conclusions based on their observations. In groups: Learners relate conclusions with the formula used to calculate kinetic energy.	From the observations made in the practical investigation learners interchange kinetic energy and work done in moving an object from one position to another.	
Teaching method and approach	Inquiry, cooperative learning, demonstration & direct instruction			
Assessment strategies	Self, peer, group, teacher			
Forms of assessment	Classwork, homework, presentation, group discussion			
Resources	Textbook, internet, chart			
Teacher reflections	Evaluating learners' responses. Providing feedback on their responses Provision of additional support.			

Appendices 10: Copy of lesson plan 3

LESSON PLAN: PHYSICAL SCIENCE	
Subject: Physical Science	Grade: 10
Lesson plan: 03	Topic: Conservation of Mechanical Energy
Duration of the lesson: 2 hours	Date: …………………

Teaching method and approach	Inquiry, cooperative learning, demonstration & direct instruction
Assessment strategies	Self, peer, group, teacher
Forms of assessment	Classwork, homework, presentation, group discussion
Resources	Textbook, internet, chart
Teacher reflections	Evaluating learners' responses. Providing feedback on their responses Provision of additional support.

Appendices 11: Concept Map and Rubric

Appendix G: Scoring Rubric for Concept Maps

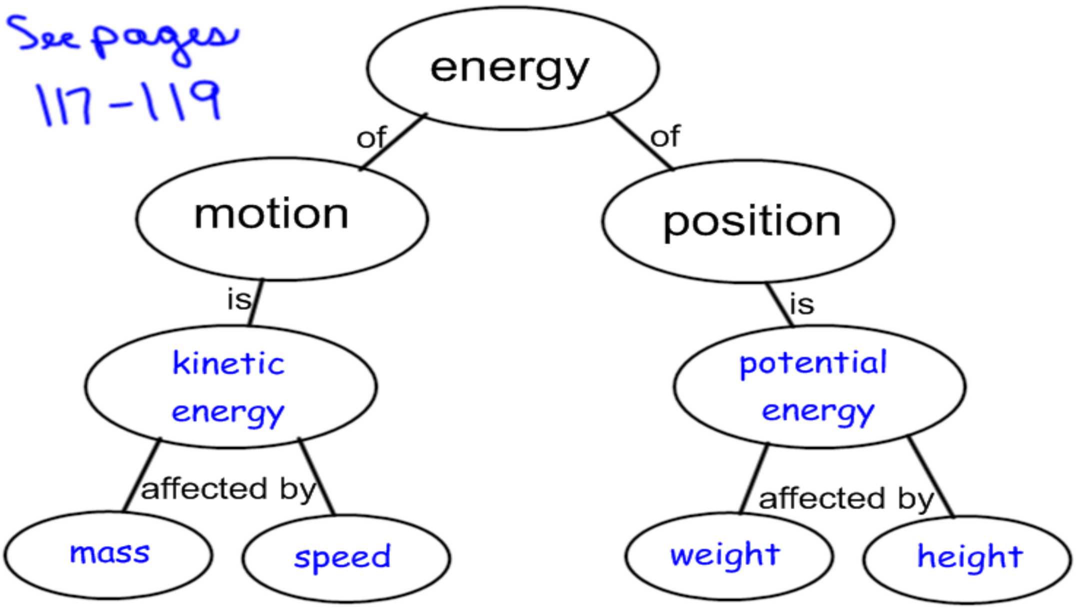
CM elements	4	3	2	1	0
Propositions	Complete, meaningful and valid.	Most are meaningful and valid.	Some are meaningful and valid.	Incomplete, few are meaningful.	Missing or not meaningful.
Hierarchy	Superordinate and subordinate concepts are present and valid.	Most but not all are present and valid	Some are present and valid.	Few are present and/or valid. Several subordinate concepts are missing.	Hierarchy is missing or invalid.
Cross links	All are valid and non trivial. Strong evidence of higher level of thinking/ in-depth conceptual understanding.	Most are valid and non trivial. Some evidence of higher level/ in-depth conceptual understanding.	Some valid but trivial. Some evidence of higher level / in-depth conceptual understanding.	Most are invalid or trivial. Little evidence of higher level / in-depth conceptual understanding.	Missing or invalid. No evidence of higher level / in-depth conceptual understanding.
Examples	Complete set; valid, illustrative, and significant.	Incomplete set; but most are present and valid, illustrative and significant.	Incomplete set; but some are present and valid, illustrative and significant.	Incomplete set; few are present and valid, illustrative or significant.	Missing or invalid.

Rubric for scoring concept maps adapted from Novak & Gowin, 1984 and Shaka & Bitner, 1996

Content: Mechanics				
Context: Energy and principle of conservation of mechanical energy				
Activities	Presentations; discussions; demonstration; evaluation & reflection	Interactive simulations; writing of a conclusion.	Presentations; discussions; calculations using the formula & observations	Discussions; presentations
Conditions for conceptual change:	**Dissatisfaction:** **In groups:** Learners discuss the following questions and present their answers to the whole class: As the book falls its velocity increases. What happens to its kinetic energy as it falls? What happens to its gravitational potential energy as it gets nearer and nearer to the ground? Learners discuss the basis of their answers. **Demonstration:** The teacher shows the learners an internet interactive	**Intelligibility:** **In groups**: Learners interact with internet simulation that show energy conversion in a pendulum between kinetic and potential; energies and their values. **In pairs:** Learners determine if the sum of their values at any point remains constant. **In groups:** Leaners write a mathematical statement as conclusion about mechanical energy at any	**Plausibility:** **Individually:** Learners calculate the value of the unknown in the formula: [mechanical energy (m.g.h. + ½ mv^2)]$_{at\ A}$= mechanical energy [m.g.h. + ½ mv^2)]$_{at\ B.}$ **In groups:** Learners find out themselves from the internet: (1) the meaning of dissipative forces that can alter mechanical energy in a system, and (2) the meaning of a	**Fruitfulness:** **In groups**: Real life examples and a chart with pictures of systems where the Principle of Conservation of Mechanical Energy is shown and explained to learners. Learners are given a chance to add more relevant systems to the list if any.

	simulation that answers the question. **In groups:** Learners reflect on and evaluate their answers based on the demonstration above.	point in the system when there are no external forces acting on the system.	closed system. Learners state the Principle of Conservation of Mechanical energy in words. **In pairs:** Learners explore the Law of Conservation of Energy; the Principle of Conservation of Mechanical Energy in the absence of dissipative forces and report on their findings.	

See pages 117-119



Appendices 12: Interview Schedule

Learner' s code: ……………………………Gender: …………….

School: ……………………………………………………………………….

Interviewer: ………………………………………Date: ………………….

1. Dissatisfaction: 1.1 What predictions did you make at the beginning of the intervention program?

   1.2 How do you feel about your prediction after exploring the interactive simulations?

2. Intelligibility: 2.1 What helped you to understand the energy concepts clearly?

   2.2 Could you relate energy concepts and did that relationship make sense to you? Explain.

3. Plausibility: 3.1 In which other ways could you define energy concepts?

3.2 How did you find the application of the knowledge learnt in unfamiliar situations?

4.Fruitfulness: What is your feeling about real life examples on the principle of conservation of mechanical energy?

Appendices 13: Copy of worksheet on Gravitational Potential Energy

1. Gravitational Potential Energy

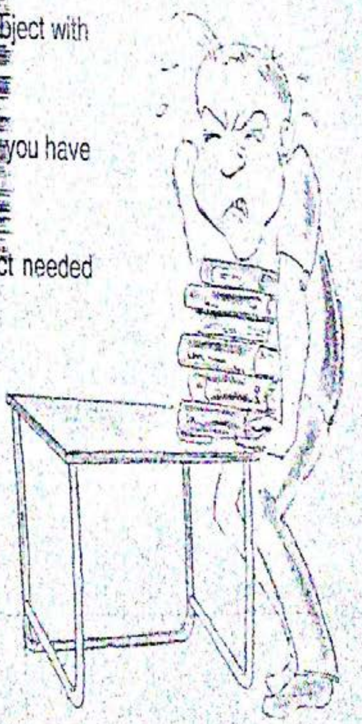
When we lift an object upward, the effort that we are putting into lifting it is stored in this object as energy. This stored energy is called gravitational potential energy. In the following activity you explore this type of energy.

1. Let the object with the smaller mass be Object 1. Let the object with the larger mass be Object 2.

2. Lift Object 1 to the height of the chair. Notice the effort that you have to put into this process.

3. Now lift Object 2 to the height of the chair. Which object needed more lifting effort? Which object is storing more energy?

4. What variable was controlled in Step 3?



5. Return your objects to the floor. Lift Object 2 to the height of the chair. Now return it to the floor, then lift it to the height of the desk. Did this require more effort than lifting it to the height of the chair?

6. What variable was controlled in Step 5?

7. When does Object 2 have more stored energy: when it is on the desk or when it is on the chair?

8. What can you conclude about the relationship between the mass of an object and the amount of stored energy when it is lifted?

9. What can you conclude about the relationship between the height of an object and the amount of stored energy?

10. Write a short summary of this experiment.

Appendices 14: Copy of learner's concept map