

Alleviating Alternative Conceptions and Conceptual Difficulties of Energy in Grade 10 Mechanics Using Contextual-Conceptual-Formal Understanding

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ABSTRACT

This study investigated learners' alternative conceptions of energy and the instructional approach in ameliorating these alternative conceptions and conceptual difficulties. The research sample consisted of fifty five (55) learners enrolled at a South African high School situated in a rural village, in the Gauteng Province. A pre-test/ post-test comparison group design was followed. Data analysis was carried out by the use of the average normalized gains. The questionnaire that served as pre- and post-test probed into learners' alternative conceptions of energy. The effectiveness of the intervention was indicated by the amount of conceptual change accomplished that followed from a calculation of the normalised learning gain. The instructional approach that progressed from contextual to conceptual to formal understanding was proved to be effective with an average normalised learning gain of 50%.

Keywords: Alternative Conceptions, Learners, Average normalized Gains, Energy, Instructional Approach, Conceptual Difficulties.

MOTIVATION AND THEORETICAL FRAMEWORK

Energy is central to all sciences, because together with matter, it makes up the universe (Hewitt, 2002: p104). Energy as an abstract concept is very difficult to teach and learn which leads to debates about how energy should be taught in early grades. (Millar 2005 and Mohan, Chen Anderson, 2009: p675). According to Mann and Treagust (2010:p145), energy is an all-pervasive phenomenon not only in science but also in everyday as humans are continually exposed to its various forms and as a consequence of this common usage of the word energy has developed a whole set of meanings in everyday life that are in conflict with the meaning assigned to the word in science In physics; energy is a basic concept that unifies the different fields of the discipline (Lemmer and Lemmer, 2007:p1). The principle of conservation of energy manifests in all sections of physics and the importance of the concepts of energy in the physics curriculum is highlighted by the

fact that in South Africa the learning area in the General Education and Training (GET) band (grade 4 to 9) that relates to physics is called Energy and Change (Cutnell, 2004: p159). The Further Education and Training (FET) band (grade 10-12) is based on concepts formed in the GET band. Research on alleviating alternative conceptions and conceptual difficulties of energy in grade 10 mechanics can consequently contribute to an improved understanding of physics as a whole.

A basic assumption of the constructivist learning theory is that learners' prior knowledge before instruction should be taken into account in constructing their conceptual frameworks (Brandsford. Brown and Cocking, 2000: p51). Several conceptual change strategies have been studied in order to alter alternative conceptions towards the scientifically accepted conceptions (Scott, Asoko, and Driver, 1992: p9; Duit and Treagust, 2003: p 671). Learners' alternative conceptions were found to be extremely resistant to change. Learning and teaching science consequently involve more than just substituting everyday knowledge with scientific knowledge (Crespo 2004: pp 1325-1326). The challenging task of the science educator is to select appropriate teaching strategies and techniques that will enhance the learning of the correct meaning and usage of scientific conceptions.

During the past decades, a great deal of research has

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been devoted to learners' alternative frameworks (Driver and Easley, 1978:p62) vis-a-vis physical phenomena. Today, it is generally accepted that learners' pre-instructional knowledge plays a crucial role in the acquisition of science concepts. Researchers like Nussbaum and Norvick (1982b: p184) and Robert (2000: pp2-4) have shown that learners' alternative frameworks that differ from scientific conceptions interfere with their learning of science. This is consistent with the constructivist notion that the internalisation (selective perception and interpretation) of new information and ideas by a person is a function of his existing conceptual framework (Ausbel 1968: p15 and Raphoto, 2008: p8). The study of learners' frameworks is based upon the assumption that if the learners' conceptions were to grow into more sophisticated understanding of physics, educators must first establish what conceptions they have, and then teach them accordingly.

In the realm of energy, a large number of studies (e.g. Mann *et al.*, 2010:p146; Duit 1981: p3, Bliss and Ogborn 1985: pp196-197; Trumper 1991: p6; Pinto, Cousa and Gutierrez, 2004: p38) have yielded valuable information about how learners understand this abstract and difficult-to-grasp concept. Watts (1983: pp214-216) classified learners' alternative conceptions of energy into the following seven categories:

- 1) Anthropocentric: Energy is associated with human beings (Mann *et al.*, 2010: p12).
- 2) Depository: Some objects have energy and expend it.
- 3) Ingredient: Energy is a dormant ingredient within objects, released by a trigger.
- 4) Activity: Energy is an obvious activity.
- 5) Product: Energy is a by-product of a situation (Mann *et al.*, 2010: p13).
- 6) Functional: Energy is seen as a very general kind of fuel associated with making life comfortable (Mann *et al.*, 2010: p11).
- 7) Flow transfer: Energy is seen as a type of fluid transformed in some processes. Frameworks number 1, 2, and 5 are the most pervasive alternative frameworks (Watts 1983: p216; Trumper 1990: pp 208-209 Mann *et al.*, 2010: p12-13).

The first research question of the study reported here is to determine whether the Grade 10 learners of a South African school hold these alternative frameworks. The concept of energy is not new to Grade 10 learners, because Energy and Change is one of the four learning areas taught in the General Education and Training

(GET) band (grades 4 to 9) (Department of Education 2003a: p5). The study of mechanics in the Further Education and Training (FET) band (grades 10 - 12) is based on concepts formed in the Learning Area Energy and Change. This emphasizes the importance to determine and remedy Grade 10 learners' alternative conceptions regarding the concept of energy.

All alternative conceptions are not unacceptable and in conflict with the accepted scientific concepts (Gilbert and Watts, 1983: p62). An example is the perception that energy is associated with human beings (framework 1). This is a limited idea that should be expanded to an understanding that all objects have energy that can be transformed or transferred. In this case, we talk about an evolutionary change that involves the facilitation of extension in richness and precision of meaning for learners' conceptions. This is one of the teaching strategies aimed to accomplish conceptual change in the science classroom reviewed by Scott *et al.* (1992: p2). Ausbel (1968: p17) described a process of meaningful learning that results in the sub-sumption of new knowledge. In this process, the new knowledge interacts with existing concepts and is assimilated into them, altering the form of both the anchoring concepts and the newly assimilated knowledge (Novak, 2004: p23). Vosniadou and Ioannides (1998: pp1215-1216) point out the value of relating conceptual change to social, cultural and situational factors.

Alternative conceptions are extremely resistant to change (Scott *et al.* 1992:p11 and Narjaikaew, 2013: p251). Learning and teaching science involves more than just substituting everyday knowledge with scientific knowledge (Hewson and Thornley 1989: pp541-542; Crespo, 2004: p1327). Although numerous perspectives about conceptual change have been proposed, the one initiated by Posner, Strike, Hewson, and Gertzog, (1982: p212) is amongst the most influential models, and has gained support from research literature and teaching practice (e.g. Hewson and Thorley 1989: p543). According to Posner *et al.* (1982: p212), learners would not abandon their tenaciously held ideas and beliefs and accept new ones unless they were dissatisfied with the former or found the latter intelligible, plausible and fruitful.

Science education researchers (e.g. Raphoto, 2008: p25, Hake 1998: p66; Kabapinar, 2004: p638) found that interactive teaching strategies such as inquiry and problem-based approaches result in higher gains in

knowledge and understanding of scientific concepts. In learner-centred science curricula such as the National Curriculum Statements of South Africa, science learning is active and constructive, involving inquiry and hands-on activities. The purpose of such activities is to develop critical thinking and problem-solving skills by posing and investigating relevant questions (Taraban, *et al*, 2007:p961). The use of a wide range of learner-centred activities improve both attitudes towards science and the learning of science (Ramsden 1994: pp7-8), which include factual recall as well as knowledge of process skills (Taraban *et al*. 2007: p962). Research has also established that disadvantaged (academically or economically or both) learners specifically benefit from activity-based programmes (Donnellan and Roberts 1985: pp119-120). Consequently, an activity-based intervention was chosen for the empirical study reported here. A variety of learner-centred instructional strategies were implemented in the intervention to provide different contexts for learning. The second research question focussed on the effectiveness of the designed activity-based learning sequence to accomplish conceptual change regarding the group of Grade 10 learners' perceptions of energy.

Science learners come to class with pre-instructional ideas that may influence the acquisition of science concepts (Narjaikaew, 2013: p260). A basic assumption of the constructivist learning theory is that these pre-instructional ideas should be taken into account in constructing learners' conceptual frameworks in science classes (Raphoto, 2008: p10). One of the common threads of constructivism that runs across all these definitions is the idea that development of understanding requires the learner to actively engage in meaning-making (Ültanır, 2012: pp196-197). Thus, constructivists shift the focus from knowledge as a product to knowing as a process. The common core of constructivist theory is that we do not find knowledge; we construct it (Boghossion, 2006:p717). From this point of view, the task of the educator is not to dispense knowledge but to provide students with opportunities and incentives to build it up (Glassersfeld, 2005:pp7-8). Several conceptual change strategies have been studied in order to alter unscientific (called alternative) conceptions towards the scientifically accepted conceptions. The challenging task of the science educator is to select appropriate teaching strategies and techniques that will enhance learning.

The approach takes into account the prior beliefs

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

Research Objective

This research sought to alleviate alternative conceptions and conceptual difficulties of energy amongst Grade 10 learners.

Research Method

Empirical Study

In order to pursue the objectives of this study a quantitative survey was done. A questionnaire was completed to determine the alternative conceptions about the concept of energy held by the Grade 10 science learners. Intervention strategies based on activity-based learning was compiled and presented to the group of Grade 10 learners. In order to assess the learners' learning gains due to the intervention, the pre- and post-test method was employed. Prior to the intervention, learners were given the compiled questionnaire as pre-test. The intervention was an instructional sequence that consisted of three activity-based lessons. Learners' involvement was considered to be the critical aspect of the activities. After the intervention the questionnaire (post-test) was administered to the same group of learners to determine the learning gain and hence the conceptual development attained.

Data Collection

Research instrument

The questionnaire developed and utilised in this study was administered to a group of fifty-five (55) Grade 10 learners. The questionnaire probed the learners' alternative conceptions of energy - both their general

perception of energy and their conceptions regarding energy in mechanics. Learners were allocated fifty minute (50) to complete the questionnaire. The time allocated for learners to answer the questionnaire was reasonable, as they managed to finish answering the questionnaire in the allocated time. The researcher supervised the completion of the questionnaire to ensure that the learners understood all the questions. The questionnaire as measuring instrument provided a basis on which the entire research effort rests. To accomplish the aim of the study, Grade 10 learners' perceptions were identified by means of a questionnaire before and after an activity-based intervention. The questionnaire that served as pre-and post- test, probed both their general perceptions of energy and their ideas regarding energy in mechanics. In the first question (Item 1), nine objects were listed, for each of which learners had to indicate whether it could have energy or not. They were asked to motivate each response. In the second question (Item 2), learners had to apply their perception of energy in explaining what happens when a man pushes a box up a hill. Thirdly (Item 3), questions were asked to determine how the learners differentiate between the concepts of energy, force and power.

Alternative conceptions about energy were identified from the pre-test results and categorized according to Watts following his seven frameworks from results of different studies.

For the sake of validity the questions of the questionnaire were discussed with another established researcher in the field, as well as some fellow colleagues in the field of science education. The reliability of the questionnaire was confirmed by the coherence in learners' responses to matched items in the questionnaire, e.g. items 1 (a), (g), 2 and 3 all relate to non living objects.

Population

The empirical study focused on a group of fifty-five (55) science learners. The learners were in Grade 10 and were enrolled at a South African High school.

Instructional Intervention

The intervention consisted of three activity-based lessons. The concepts of work, potential energy, kinetic energy and conservation of energy were introduced. For each of these concepts, the order proposed by Lemmer and Lemmer (2005:pp214-215) was followed, i.e.

progression from contextual to conceptual activities to formal problems. The intervention was compiled by the author. His own ideas and activities were integrated with examples given in the Grade 10 textbook of Brookes *et al.* (2005:pp20-21). The activities were performed in small groups so that co-operative learning could take place. There were three boys and three girls in each group.

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

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

The concepts of gravitational potential and kinetic energy were formalised in the third lesson. The learners conducted an inquiry experiment showing them that kinetic energy depends on both the mass and velocity of an object. The learners studied the transfer of energy between two colliding balls as well as the conversion of the energy of a swinging bob. Conservation of energy during transformations was explained.

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

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

height. The bob reached its greatest velocity (v) at the lowest point, its kinetic energy at that point being $E_k = \frac{1}{2}mv^2$. The educator explains the concept of conservation of mechanical energy.

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

Concept Formation

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

Gravitational Potential Energy

Gravitational potential energy is "stored" energy that a body has because of its position in the earth's gravitational field. The formula for gravitational potential energy is $E_p = mgh$, where m is the mass of the body, g is the gravitational acceleration, and h is the vertical displacement (increased). After defining the concept, the educator asked the learners to answer the question related to this concept given on the activity sheet. Learners were supposed to calculate the gravitational potential energy gained by a non-living object (box) of a mass of 150 kg when it is raised through a vertical height of 20 m. Take $g = 10 \text{ m.s}^{-2}$.

Kinetic Energy

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

Inquiry Experiment: Kinetic Energy

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

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

According to Hake (2002a: p3), the average normalised gain affords a consistent analysis of pre- and post-test data over a diverse learner population. The average normalised gain can be calculated by means of the following formula (Hake,2002a:p3):

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

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

The average normalised gain is a much better indicator of the extent to which a treatment is effective than is either the actual learning gain or the post-test results (Hake 2002b:p3; Meltzer 2002:p1259). If the

treatment (e.g. an intervention) yields an average normalised gain larger than 0, 3 for a course, the course can be considered to be in the "interactive-engagement zone" (Hake 2002b:p3).

Results and Discussion

Table 1 summarises the learners' responses to the first pre-test item of the questionnaire. They had to indicate whether or not the listed objects possessed energy.

Table (1)

Learner's Responses

Can The Following Objects Possess Energy? Item 1	Yes Response		No Response	
	Number	%	Number	%
a) Rock	23	42	32	58
b) Tree	33	60	22	40
c) Dog	37	67	18	33
d) Learner	54	98	1	2
e) An apple hanging on a tree	15	27	40	73
g) Non-living object, such as a ball	19	35	36	65
i) Does a sleeping dog possess energy?	21	38	34	62
k) Food	18	33	37	61
l) Fuel	10	18	45	82

Discussion of Pre-Test Results (Item 1)

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

a) Rock

Twenty-three (42%) of the learners indicated that the rock possessed energy. The most common reason "given was that it was heavy" (15%) or "that it contained sand or water". These reasons referred to the features of the rock. The learners also gave reasons that related to what could be done with a rock, namely that "you use energy to pick it up or throw it" (11%) or that "one could use it for building" (9%). The depository model of energy as well as the functional model was displayed by these learners (Wesi, 2003:p260).

The thirty-two (58%) of the learners who responded that a rock could not possess energy, mainly gave a reasons that "a rock did not live" (18%) nor "did it move" (15%). They consequently held a human-centred model of energy, or related energy to activity (Wesi, 2003: p260).

b) Tree

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

displayed. The 9% of the learners who said that the tree got energy from the sun gave a scientifically acceptable answer.

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

c) Dog

Thirty-seven (67%) of the learners indicated that a dog possessed energy. According to 22% of the learners, the dog had energy because "it could run"; while 18% said that "it was living". The human perception that energy was associated with a living thing was displayed. The 15% of the learners who said that a dog had energy because it was an animal attributed human features to animals. The perception that energy and power were the same concept was displayed by 11% of the learners. They used the terms energy and power interchangeably, which is a problem.

Of the 33% learners who responded that a dog did not possess energy, 11% "said it was not a human being and it was not strong". The energy as human-centred perception was displayed again. Some 11% gave a variety of reasons and 4% gave no reason at all.

d) Learner

Fifty-four (98%) of the learners indicated that a learner possessed energy. The most common reason given was that "she/he was living" (36%). The learners

also gave as a reason the fact that *“the learner could eat”* (18%). As in the previous cases, the majority of learners revealed a human-centred view. One (2%) of the learners who responded that a learner could not possess energy gave as a reason that *“a learner had energy when she/he used it”*. This indicates their usage of the depository model of energy.

e) An apple hanging on a tree

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

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

g) Non-living object such as a ball

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

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

i) Does a sleeping dog possess energy?

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

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

j) Does force cause the change to the motion?

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

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

k) Food

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

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

1) Fuel

Ten (18%) of the learners indicated that fuel possessed energy, the most common reason given being that *“it made a car move”*(5%); *“it had power”* (4%) and *“fuel had energy only in cars”*(4%). The other 2% of learners said that *“fuel had chemical energy”* - a scientifically accepted answer. The 82% of learners who indicated that fuel could not possess energy, said we *“could not drink it”* (33%), *“it was a gas”* (22%) and *“it was not good for a human being”* (2%). The other (7%) gave a variety of reasons.

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

Table 1 summarises the pre-test results of the first question in which the learners had to indicate and motivate whether the given objects could have energy. The number of learners who answered YES or NO was

given, and the motivations for their answers were discussed. These results were further analysed to determine the frequencies of occurrence of the different alternative conceptions revealed by the learners. Five of seven categories of alternative conceptions regarding energy as identified by Watts (1983) were found in the learners' responses who clearly demonstrated the alternative perceptions. The other learners either did not give a reason, or gave dissimilar reasons.

The results summarised show that the human-centred perception occurred in all the cases, i.e. for all the objects listed in Item 1. Sometimes, it was even used by learners who agreed as well as those who disagreed that the given object could have energy. For example, in the case of the dog, human-centred responses in support of a dog having energy were that it was living, while human-centred responses that differed from this statement included that a dog was not strong or was not a human being. Another commonly found alternative conception was the association of energy with activity, specifically movement. Responses that referred to energy as causal agent, i.e. a source of activity based on energy stored within it, were categorised as the depository model. Examples of energy sources are food and fuel.

Some learners perceived various objects to be functional, e.g. a rock, learner, food and fuel. These objects could either be used to do something (e.g. a rock can be used for building) or can do work itself (e.g. a learner) or it provides energy to a human or car to do

work (the food and fuel). According to the energy as ingredient perception, some learners considered energy as a dormant ingredient within objects that needed a trigger to release it. For instance, food (including apples) gave energy to people when they ate it, while fuel only provided energy when it was used inside a motor car.

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

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

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

Items Referring to Force and Energy

Three items were included in the questionnaire in order to determine how learners differentiate between the concepts of force and energy. The results are summarized in Table 2.

Table (2)

Results for items referring to energy and force

Question	Yes Response		No Response	
	Number	%	Number	%
f) Is energy, power and force the same concept	40	73	15	27
h) Does energy cause motion?	44	80	11	20
j) Does force cause motion?	40	73	15	27

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

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

The fifteen (27%) of the learners who responded that energy, power and force were not the same concepts did

not explain the terms scientifically. Only 2% of the learners said "*they were not the same concept because they did not perform the same job*". The other 25% of learners mostly gave no reason at all.

h) Does energy cause motion?

Forty-four (80%) learners indicated that "*energy caused motion*". The most commonly used reason was that "*movement of any kind involved energy*" (22%). The perception of energy as an activity was revealed by the learners. The other learners reasoned that "*energy caused something to occur*" (15%) or energy was "*the ability to*

do things” (15%). These latter reasons differ from the scientific definition that energy is the ability to do work, where the concept of work has a specific meaning.

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

j) Does force cause motion?

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

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

Pre-test results: Items 2 and 3

The results obtained for items 2 and 3 of the

questionnaire are as follows:

Item 2

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

Item 3

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

Post-test results

Post-test results Item 1

The results of the post test are displayed in Table 3

**Table (3)
Post-Test Results (N=55) For Item 1**

Item 1 Can The Following Object Possess Energy			NO	
	Number	%	Number	%
a) Rock	40	73	15	27
b) Tree	30	55	25	45
c) Dog	50	91	5	9
d) Learner	55	100	0	0
e) An apple hanging on a tree	50	91	5	9
g) Non-living object such as a ball	40	73	15	27
i) Does a sleeping dog possess energy?	44	80	11	20
k) Food	48	87	7	13
l) Fuel	43	78	12	22

Analysis of Post-Test Results

Item 1 (a)

The energy possessed by the rock was named as potential energy by 40 (73%) of the learners. The other learners did not give a reason why they said a rock had energy. Approximately a quarter of the learners (27%) clung

to their perception that a nonliving rock could have energy.

Item 1 (b)

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

Item 1 (c)

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

Item 1 (d)

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

Item 1 (e)

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

Item 1 (g)

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

Item 1 (i)

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

Item (k)

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

Item (i)

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

Item (2)

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

Item (3)

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

Analysis of post-test results for force and energy

The responses of learners to the items regarding the concepts of force and energy are given in Table 4. A discussion follows below the Table 4.

Table (4)
Post-test results for force and energy

Question	Yes Response		No Response	
	Number	%	Number	%
f) Are energy, force, and power the same concepts	5	9	50	91
h) Does energy cause motion?	46	84	9	16
j) Does force cause motion?	49	89	6	11

Item (f)

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

Item 1 (h)

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

Item (j)

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

Discussion of the post-test results

The concept of potential energy

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

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

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

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

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

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

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

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

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

Alternative Conceptions

Although the majority of the learners showed a conceptual change towards the scientific concept of energy, some of them still revealed alternative

conceptions in the post-test, namely:

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

All five categories of alternative conceptions occurred in some of the learners' responses. The human-centred association of living beings with energy has been found to be one of the most pervasive alternative conceptions. This is in accord with results obtained by other researchers (e.g. Trumper 1990:p353).

Scientific Terminology

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

Average Normalize Gains

The average of the results from pre-test to post-test increased tremendously namely from a pre-test average of 49.4% to a post-test average of 83.1%. The gain is 0.5 (or 50%). The average gain of 50% falls in the "interactive engagement zone" (Hake 2002b:p3). The effectiveness of the strategies used in the intervention is thus comparable with contemporary interactive engagement strategies.

Table (5)
Average Normalised Gains Obtained Per Item

Item 1	Pretest	Post-Test	Improvement	Gain	Percentage Gain
	%	%	%		
A	42	73	31	0.53	53
B	55	60	5	0.1	10
C	67	91	24	0.72	72
D	98	100	2	1	10
E	27	91	64	0.88	88
F	27	91	64	0.88	88
G	35	73	38	0.58	58
H	80	84	4	0.2	20

Item 1	Pretest	Post-Test	Improvement	Gain	Percentage Gain
	%	%	%		
I	38	80	42	0.68	68
J	73	89	16	0.59	59
K	33	87	54	0.8	80
L	18	78	60	0.73	73
Average	49.4	83.1		0.5	50

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

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

Conclusion and Recommendations

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

The first objectives of the empirical study were to determine the alternative conceptions of Grade 10 learners about the concept of energy and identify them in terms of the classification of Watts (1983). This objective was accomplished by means of a questionnaire. The questionnaire established the group of Grade 10 learners'

ideas about what energy is as well as how they applied these ideas. On ground of these results an instructional sequence comprising of activity-based lessons in mechanics was compiled and tested. The instructional sequence progressed from contextual to conceptual to formal learning. The effectiveness of the intervention (aim of the study) was determined by calculation of the average normalized gain.

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

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

The high percentage of occurrence of learners' alternative conceptions about energy and their deficiency in an understanding of the scientific concepts as revealed by the pre-test is disturbing. The Grade 10 learners had been exposed to the concept of energy from grades R to 9 in the physics syllabus *Energy and Change*. During these years of instruction their alternative conceptions were not sufficiently taken into account (Edwards 2007:p20). It also seems that scientific terminology such as potential and kinetic energy and force were not introduced effectively.

The activity-based sequence of this study that

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

The poor pre-test results show that the learners' alternative conceptions were not efficiently addressed in lower grades. This could be due to different factors e.g.

strong association with their vernacular conceptions, ineffective teaching and inappropriate textbooks. This result necessitates an investigation into what science is learnt and how it is learnt in all grades. There is a special need to understand how learners learn physics concepts in African languages without introducing or enhancing alternative conception in the classroom.

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

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تخفيف الصعوبات المفاهيمية فيما يخص الطاقة لطلاب الصف العاشر ميكانيكياً باستخدام سياق المفاهيم الرسمية

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ملخص

يهدف هذا البحث إلى دراسة المفاهيم البديلة للمتعلمين فيما يخص الطاقة وأثر النهج العلمي في التخفيف من صعوبة المفاهيم والتصورات البديلة. وقد اشتملت الدراسة على عينة بحث مكونة من (55) متعلماً رسمياً في مدارس جنوب إفريقيا الثانوية والموجودة في القرى الريفية في مقاطعة جوتينغ. الكلمات الدالة: المفاهيم البديلة، المتعلمين، الطاقة.

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