Chapter 3

Understanding Energy Conservation: Intersection Between Biological and Everyday Life Contexts

Vivien Mweene Chabalengula and Frackson Mumba

Additional information is available at the end of the chapter

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1. Introduction

Energy and energy conservation (which is also the First Law of Thermodynamics) are such closely related concepts that it is almost impossible to discuss one without the other in a closed system (Goldring & Osborne, 1994). Energy is commonly defined as the *capacity to do work* (Lee & Liu, 2010), such as driving metabolic reactions and processes (e.g. photosynthesis, muscle contraction) in biological systems. On the other hand, the energy conservation principle is commonly stated as *energy cannot be created or destroyed* (Raven & Johnson, 1999) in almost all science textbooks. However, many science educators argue that this definition may be confusing among students if supporting concepts such as energy transfer, energy flow, and energy transformation (Mclldowie, 1995; Chabalengula et al, 2012) are not incorporated when defining energy conservation. This is because all energy forms are inter-convertible from one form to another without any *loss*; and any apparent loss of energy can be explained as the conversion/transformation of energy into some other form (Raven & Johnson, 1999; Solomon et al, 1993).

The concepts of energy and energy conservation are central scientific ideas which provide an important key to our understanding of the way things happen in the biological, physical, and technological world (Liu, Ebenezer & Fraser, 2002). Furthermore, energy is one of the science concepts that cuts across all science disciplines, and is experienced in our everyday life situations (Saglam-Arslan & Kurnaz, 2009).

However, the synonymous use of the terms *conservation* and *saving* in everyday language usage causes students to misunderstand the scientific meaning of the energy conservation principle. With the current national and global debates on energy saving reality coming to agenda with energy crisis, many students think of energy conservation as energy saving because the latter term is used when issues on depleting energy sources are discussed in media and political realms (Tatar & Oktay, 2007). As such, it is imperative that school-going citizens are scientifically literate about what energy conservation is if they are to delineate energy conservation and energy saving. Therefore we propose that it is vital for science educators to determine students' understanding of energy conservation from a scientific (particularly biological context) and an everyday life context. These two contexts are particularly important because they are interrelated in that biological contexts such as jogging and breathing are always experienced by students on each daily basis so much that they can relate to them very well. Therefore, a compilation of students' understanding of energy conservation based on these two contexts would provide a set of energy conservation data that can be used as a basis for science education curriculum development and instructional design in schools (Lee, 2011).

1.1. Energy conservation principle

According to the energy conservation principle (also known as the first law of thermodynamics), energy cannot be created or destroyed; instead it can be converted from one form to another (Raven & Johnson, 1999; Solomon et al, 1993). All energy forms are inter-convertible from one form to another without any '*loss*'. Any apparent loss of energy can be explained as the conversion of energy into some other form. For example, in biological/living systems, some of the energy is used to drive metabolic processes and some of it dissipates to the atmosphere in the form of heat. Therefore, energy as a conserved quantity at the system level is built upon many supporting concepts such as energy source, energy transfer, energy flow, and energy transformation (Mclldowie, 1995).

The description of energy flow and transformations is frequently used in many biological and technological applications (Ametller & Pinto, 2002; Lin & Hu, 2003). For instance, in biological systems, energy flows from sources such as the sun and moves through a number of carriers to eventual receivers, such as through producers (mostly plants which utilize energy to produce food during photosynthesis) to consumers (animals) in food chains. That is, plant cells transform light energy to chemical energy stored in chemical bonds of food materials. When some herbivores eat the plants, some of this chemical energy is eventually converted to mechanical energy in animals for muscle contraction (useful work), whereas some of it may dissipate to the atmosphere in form of heat energy (Raven & Johnson, 1999). As all these metabolic processes are happening, there is no loss; instead any seemingly loss is explained in terms of energy conversion/transformation. Given the scientific viewpoint of energy conservation especially in biological systems, it is important to remind readers that this concept poses conceptual difficulties among students, as highlighted in the next section.

1.2. Problematic concerns about energy conservation in biology education

As stated earlier on, the energy conservation principle is commonly stated as energy cannot be created or destroyed in most science textbooks. Due to its common appearance in textbooks and its short definition, Tatar and Oktay (2007) point out that energy conservation is one of the most known science principles among students as it is easy to state and remember. As such when asked to state the energy conservation principle, many students tend to recite it with relative easiness, but they are unable to correctly apply it to biological systems. Therefore, the two problematic aspects that make energy conservation a difficult concept to understand among students are:

a. Despite being able to recite it correctly, many students are unable to apply this principle, particularly to biological systems and processes as well as in everyday life situations involving energy (Chabalengula et al, 2012). Part of the reason for this problem has been highlighted by Driver and Warrington (1985, p. 171) who asserted that "very rarely do students consider energy as a conserved quantity; rather it is something that is active for a short period and then disappears".
b. The synonymous use of the terms *conservation* and *saving* in daily life causes students to misunderstand the energy conservation principle (as discussed earlier on).

The two problems stated above led to our motivation to look at the science education literature and determine the extent to which the science education research has tried to remediate the problems. Two issues became evident: First, a review of the previous instruments aimed at diagnosing students' understanding of energy conservation shows that the focus was mainly in physics and engineering contexts rather than in biological contexts. Second, very few studies have used test items which reflected the everyday life situations despite the findings that students have ideas about energy conservation from this perspective. In our opinion, the students' conceptual difficulties with respect to energy conservation are interrelated and connected to other aspects such as everyday life and science discipline contexts, which have not been sufficiently taken into account in previous diagnostic research.

Therefore in this book chapter, we will present findings from the diagnosis we conducted with 90 university biology students' understanding of energy conservation using the pencil and paper test, reflecting test items phrased in the biological and everyday life situations, we developed specifically for this study.

1.3. Previous studies on students' understanding of energy conservation

The science education research has shown that students of all ages have conceptual difficulties and misunderstandings related to the meaning of energy conservation (e.g. Goldring & Osborne, 1994; Pinto et al, 2005), and the application of energy conservation in biological systems (e.g. Barak et al, 1997; Eisten & Stavy, 1988; Fetherston, 1999; Gayford, 1986; Goldring & Osborne, 1994; Kesidou et al, 1993; Kruger et al, 1992; Linjse, 1990; Mann, 2003; Solomon, 1982; Trumper, 1997).

Table 1 shows some previous studies (in chronological order) and the corresponding student errors about energy conservation meanings and applications in biological systems. With respect to what energy conservation means, several researchers have found two common errors: energy conservation means energy saving; and energy conservation is

Some erroneous ideas about energy conservation, as identified by different researchers	Solomon (1982) n=one class (English comprehensive school)	Gayford (1986) n=296 (English A-level biology	Eisten et al (1988) n=188 (Israeli high school & university	Linjse (1990) n=97	Kruger et al (1992) n=159 (English primary school teachers)	Kesidou et al (1993) n=34 (German high school students)	Goldring et al (1994) n=75 (English high school students)	Barak et al (1997) n=104 (76 & 28 Israeli high school	Trumper (1997) n=189 (Israeli pre-service biology	Fetherston (1999) n=94 (Australian high school students)	Mann (2003) n=610 (Australian high school students)	Pinto et al (2005) n=20 (Spanish high school science
Errors relating to meaning of energy conservation												
Energy conservation is synonymous to energy saving							30%					*
Energy conservation is the opposite of energy degradation												*
Errors relating to application of energy conservation in biological systems												
Students' responses to energy-related concepts do not reflect (or if they do, contradict) the idea of energy conservation in biological systems		79%		*	*	100 %	31%	*	*		*	
Energy is **created or formed** during respiration			**7%**									
Energy is **used up or consumed** during processes in living things				*		29%				15%		
Energy **loss** & **decrease** during physical activities (e.g. exercises) in living systems are erroneously interpreted as a decrease in its quantity	*											*

Table 1. Summary of students' erroneous ideas about energy conservation
Note: *represents that a corresponding error was observed, but no exact percentages of students holding the error was given.

opposite of energy degradation. With respect to the application of energy conservation, many researchers have found a conceptual failure among students to apply the energy conservation principle (energy cannot be created or destroyed) to biological situations involving energy. That is, the most common errors identified are: energy is created or formed during respiration; energy is used up or consumed during metabolic processes; and energy is lost during physical activities in living organisms. Energy loss and decrease in energy phases are erroneously interpreted as a decrease in its quantity, and not a decrease in energy's usefulness (a correct scientific viewpoint). Scientifically, all energy forms are inter-convertible from one form to another without any loss of energy. Similarly, in all biological processes there is the same amount of energy before as after an event (Starr &Taggart, 1992). However, as shown in Table 1, previous research shows that many students do not realise that energy is conserved in biological processes and systems. Kesidou et al (1993) explain that students often reject the idea of energy conservation because it seems to contradict everyday experiences and language usage where energy is often viewed as being produced and consumed, but not conserved. As such it is important to point out here that some students who seem to have erroneous ideas about energy conservation may be influenced by a language problem, and not a conceptual one. It is possible that whilst students use terms such as *used up* and *lost,* some of them may use these terms figuratively, and not actually conceptualize energy as not being conserved.

1.4. Aims of the chapter

Based on the concerns outlined above, and the previous studies done on students' understanding of energy conservation, the aims of this chapter are three fold: (a) To present the data and results we found on students' understanding of energy conservation in biological and everyday contexts; (b) To develop a diagnostic instrument which can be used to diagnose students' understanding of energy conservation; and (c) To provide suggestions on how biology educators can design their science curriculum and instruction in order to help students understand and apply the concept of energy conservation to biological systems.

The three research questions that guided this study were: (1) Are students able to state the energy conservation principle? (2) To what extent are students able to apply the energy conservation principle to everyday life situations involving biological phenomena? (3) Do students understand what happens to energy during metabolic processes in biological/living organisms?

2. Data collection methods and analysis

2.1. Sample description

The sample consisted of 90 first-year biology students at a South African university. There were 40 males and 50 females. All these students were in a pre-medical program in which they were preparing to go to medical school.

2.2. Development of energy conservation diagnostic test

A survey approach was used for this research, using a pencil-and-paper diagnostic test specifically developed to collect the data. The design of the diagnostic test was based on a process described by Haslam and Treagust (1987). The development of the test involved two main phases: the preparatory and the test formulation phases. The preparatory phase involved three steps. Step 1 involved the drawing up a list of scientifically acceptable propositional knowledge statements about energy conservation and in biological-context. This list was drawn up after interviewing three biology lecturers and then consulting the two prescribed tertiary level textbooks for first-year biology courses at the university where the study was conducted (i.e. Raven & Johnson, 1999; Solomon *et al.*, 1993). The purpose of this step was to draw up the energy conservation conceptual structure that defined this study, and which was used as a guide when constructing the test items, and when marking the answers. The energy conservation conceptual structure we came up with is summarized below:

- According to the first law of thermodynamics (the law of conservation of energy), energy cannot be created or destroyed, but it can be converted from one form to another work.
- All energy forms are inter-convertible from one form to another without any *loss*.
- Any apparent loss of energy can be explained as the conversion of energy into some other form. For example, during each energy conversion in living systems, some of the energy is used to drive the metabolic processes and some of it dissipates to the atmosphere in the form of heat.
- In biological systems, most reactions of organisms involve a complex series of energy transformations. For example, during photosynthesis, plant cells transform light energy to chemical energy stored in chemical bonds of food materials. Some of this chemical energy may eventually be converted to mechanical energy in animals for muscle contraction, if the plant is eaten by an animal.

Step 2 involved compiling a list of common erroneous ideas about energy conservation, reported in the research literature (see Table 1). The purpose of this step was to compile a list of ideas about energy conservation held by students in previous research studies, so these could be included in the diagnostic test to be developed. Step 3 involved defining the content boundaries of the test so that topics which students were expected to know when they enter first year would be included in the test, in order for the test to be used to diagnose prior knowledge as well. The information for this step was acquired through interviews with lecturers who provided data on the prerequisite knowledge required in first year biology.

In the test formulation phase, the diagnostic test had to fulfill two basic criteria: checks basic knowledge about energy conservation; and tests understanding of energy conservation. Testing for understanding is not an easy matter. Various authors have listed criteria that could be used in judging understanding. For example, Sanders and Mokuku (1994) stated that individuals who understand a concept should: know and be able to recognize the name and definition of a concept; be able to define and explain the concept in their own words; be able to recognize instances not previously encountered of the concept; be able to distinguish between and classify instances and non-instances of the concept not previously encountered; and be able to apply the concept to new situations. Through these criteria, it is possible for science educators to determine for sure, their students' understanding level. A number of these criteria were considered when designing the test. For example, the test items were constructed in such a way that students were required to state *energy conservation* in their own words, and to apply their understanding of energy conservation in the closed statements reflecting biological and everyday life scenarios.

2.3. Energy conservation diagnostic test

The test consisted of three questions. Question 1 was an open-ended and aimed at eliciting students' understanding of the energy conservation principle. Actual Question 1 read: *What does the energy conservation principle state?* Question 2 consisted of closed-ended statements phrased in everyday life contexts but reflecting biological phenomena (see Table 3 for the actual statements). These statements were meant to determine the extent to which students are able to apply their understanding of energy conservation in the biological and everyday life situations. The actual Question 2 read: *Below are some statements about energy reflecting everyday life situations and biological phenomena.* Task 1 *(a) For each statement, indicate by placing a tick (✓) in the appropriate box if the statement is scientifically correct or incorrect; (b)Then indicate how sure you are that the answer you have provided is correct by ticking the appropriate box on "Sure", "Think so" or "Guessing"*. Task 2 *(a) If the statement is incorrect, underline the word or phrase in the statement which makes it incorrect; and (b) Then write in a word or phrase which would make the statement correct*. Question 3 was open-ended and was meant to elicit students' conceptual understanding of what happens to energy during metabolic processes in living organisms. The actual question 3 read: *Energy is required to drive metabolic processes (such as breathing, muscle contraction) in living organisms. Explain what you think happens to energy during metabolic processes.*

Quality-control steps taken while the instrument was developed included checks on content validity, and rigorous face validation by three university biology experts. The instrument was piloted with 30 first-year biology students who were not involved in the main study. Piloting is an important quality-control procedure as it enables to check on the suitability of individual test items; to gain feedback on how well participants understood the questions, response procedures and instructions so that questions can be improved (Bell, 1987). The pilot group was requested to indicate whether they had problems understanding what they were required to do in each question and each closed statement. They were also further requested to write down the words or phrases which were not clear to them. The results of the pilot showed that majority of the students who indicated having problems suggested their inability to give answers due to lack of knowledge about energy conservation, and not based on misunderstanding the items. As such all test items were maintained.

3. Data analysis

The data were analysed using open-coding and reported as frequency counts and percentages. After a line-by-line analysis of each script, categories and sub-categories to which responses would fit well were developed. The categories which had been developed were given to two biology experts for validation. These experts were asked to check for the following: the scientific correctness of the answers given by students, the appropriateness of the categories developed for the student answers, and whether the students' responses were correctly categorised. This was done by giving each expert ten scripts to go through and code independently. Any differences in the coding were discussed collectively, and a common agreement reached. When individuals rate a product, there is always a possibility that some portion of the agreement between them is due to chance. As such, Cohen (1960) recommends using the kappa statistic to assess interrater agreements involving nominal scale. Cohen's Kappa (k) is a coefficient of interrater agreement that takes into consideration agreement by chance. The interrater agreements between the biology educators on the scientific correctness of the answers provided by students are shown in Table 2.

Test item	Percent agreement	Kappa value
Definitions of energy conservation principle.	96	0.90
Explanations of what happens to energy during metabolic processes.	87	0.85

Table 2. Interrater agreement values

The percentage of agreement ranged from 87 % to 96% with a corresponding kappa coefficients range of 0.85 to 0.90. The percentage agreement of more than 75% and kappa values above 0.5 are considered to indicate good level of interrater agreement (Chiapetta, Fillman & Sethna, 1991). Therefore, the values in this study can be considered good enough to justify reliability. After the categorization process on the scientific correctness of the responses, frequency counts were conducted to get the actual number of students giving each answer, and to calculate the percentages.

4. Results and discussion

The results have been presented along with the discussion. This is because certain aspects of energy such as what happens to energy during metabolic processes need to be discussed alongside the scientifically acceptable perceptions so that the reader(s) can have a clearer perspective as to why the authors of the current study categorized some statements as scientifically correct or incorrect.

4.1. Stating the energy conservation principle

Nearly all students (98%) correctly stated the principle of energy conservation (i.e. energy cannot be created or destroyed). This finding is supported by Tatar et al (2007) who pointed out that this principle is widely known among students due to its easiness in stating and remembering so much that when asked to state it, students do recite it correctly.

However, majority of the students in this study still reverted back to their everyday understanding of energy being *used up*, *created* or *lost* during activity, when they had to apply this principle in closed-ended biological and everyday context statements. This implies that even though these students can correctly state the energy conservation principle, they do not understand it fully so as to apply it to biological situations.

4.2. Application of energy conservation principle in biological situations

Students' understanding and application of energy conservation were elicited using the closed statements that involved biological phenomena presented in everyday life situations, as shown in Tables 3 and 4. Table 3 shows students' responses on the correctness of each statement, and their confidence level of their answers. Table 4 shows students' responses on word/phrase they believed made a statement incorrect, as well as the word/phrase they would write-in to make a statement correct. However, one important point to note as one reads the results in this section is that many students (38%) did not attempt to underline the word or phrase making the statement(s) incorrect, or to write in the word or phrase which would correct the statement(s) which they had indicated were incorrect. The possible validity problem associated with this is that it is not clear whether the students who did not give responses did not follow the instructions, or whether this indicated a lack of understanding of the energy conservation principle. As such, it would have been of value to interview some of these students. However, interviews were not conducted because one of the purposes for this study was to develop a pencil-and-paper diagnostic test that could be used to diagnose students understanding of energy conservation, and which biology educators can easily administer. The specific findings pertaining to students' ability to apply the energy conservation principle are provided in the next subsections.

Test Statements	**How sure are you statement is correct**				**How sure are you statement is incorrect**			
	Statement Correct	Sure	Think so	Guessing	**Statement Incorrect**	Sure	Think so	Guessing
If you go jogging, energy is used up*.	**83 (92%)**	73 (88%)	10 (12%)	0	**6 (7%)**	5 (83%)	1 (17%)	0
After exercise, you can build up your energy levels by resting*.	**39 (43%)**	18 (46%)	17 (44%)	4 (10%)	**50 (56%)**	17 (34%)	32 (64%)	0

When you are asleep your body does not require any energy because it is not active*.	**6 (7%)**	4 (67%)	2 (33%)	0	**83 (92%)**	71 (86%)	9 (11%)	0
During exercise, energy is built up in the body*.	**14 (16%)**	6 (43%)	7 (50%)	0	**74 (82%)**	47 (64%)	23 (31%)	3 (4%)
When living things are active, they lose energy*.	**53 (59%)**	30 (57%)	18 (34%)	3 (6%)	**36 (40%)**	20 (56%)	15 (42%)	0

Table 3. Students' responses on correctness of statements, and how sure they were about their answers.
Notes: Figures outside the brackets represent the actual number of students who responded.
* Statement is scientifically incorrect.

Number of students who did not attempt the test item 34 (38%)								
Number of students who responded to the test item 56 (62%)								
	Task 1				**Task 2**			
Statements reflecting biological phenomena	**Underlined word or phrase which makes statement incorrect**	Actual number of students	% of who responded	% of whole	**Written-in Word or phrase which makes statement correct**	Number of students	% of who responded	% of whole sample
If you go jogging, energy is used up*	Incorrect phrase -used up	4	7	4	Acceptable - converted to different forms Unacceptable -lost	3 1	5 2	3 1
After exercise, you can build up your energy levels by resting*	Incorrect phrase -build up	9	16	10	Acceptable -do not build up	4	7	4
	Incorrect word -resting	22	39	25	Acceptable -eating(food consumption) Unacceptable -stop using energy	15 3	27 6	16 4

When you are asleep your body does not require any energy because it is not active*	Incorrect phrase -does not require energy because it is not active	47	84	52	Acceptable -require energy as it is still active - many body processes (e.g. respiration) still occur	21 8	37 14	23 9
During exercise, energy is built up in the body*	Incorrect phrase -built up	42	75	47	Acceptable - converted to different forms Unacceptable - used up - lost	7 23 7	12 41 13	8 26 8
When living things are active, they lose energy*	Incorrect word -lose	25	45	28	Acceptable -convert it to different forms Unacceptable -use up	7 10	12 18	7 11

Table 4. Students' responses on words/phrases making the statements incorrect, and how they would correct them.
Note: * Statement is scientifically incorrect

4.2.1. Ideas relating to energy being used up when an organism is active

The idea that energy is *used up* during activities was erroneously accepted by majority of the students. That is, 92% of them erroneously indicated that the statement *If you go jogging, energy is used up,* is correct and most of these students (73 of them) were sure their response was correct. To the contrary, only 6 students correctly indicated that the statement is incorrect. When asked to underline the phrase making the statement incorrect, only four of the six students (who indicated that the statement was incorrect) correctly underlined the phrase *used up*. Three of these students correctly wrote in the phrase "energy is converted into different forms". One student wrote in the word *lost*, however without the added explanation that heat energy is lost to the body during respiration, this answer has to be judged as erroneous.

The idea that energy is *used up* during activities and in processes is documented by many researchers (e.g. Linjse, 1990; Kesidou & Duit, 1993; Fetherston, 1999). For example, Kesidou et al found that 29% of the students gave an explanation in which they explicitly employed the ideas of energy being used up. In another study by Fetherston (1999), a much smaller percentage of students (15%) erroneously stated that energy is *used up* during processes in living things. A similar finding was documented by Kesidou et al (1993) and Fetherston (1999) in which high school students had an erroneous view that energy is used up.

Scientifically, energy cannot be used up, instead, it remains constant despite the energy changes which occur, according to the First Law of Thermodynamics. However, in everyday language usage, energy is viewed as a substance which becomes used up in situations dealing with activity such as exercises. Many students may erroneously conclude that "energy is used up, as in batteries which go flat" or "when food is eaten" or during activities (Kesidou et al, 1993; Fetherston, 1999).

4.2.2. Ideas relating to energy being built up when an organism is at rest or active

Two statements tested the idea that energy can be *built up*. Almost half of the students in the sample (43%) erroneously indicated that the statement *After exercise, you can build up your energy levels by resting* is correct, although 17 of them had doubts about whether their answer was correct. However, quite a large number of the students (56% of them) correctly indicated that the statement was scientifically incorrect; although very few of them (17) were sure their response was correct. The majority (32) seemed to be unsure that their answer was correct. When asked to underline the word/phrase that made the statement incorrect, nine students correctly underlined the phrase "build up" as being erroneous. However, when it came to writing-in the word/phrase to correct the statement, very few students did so. For instance, only one student correctly wrote-in the phrase "do not build up" to correct the statement.

The statement *During exercise, energy is built up in the body*, also tested whether students agree that energy is "built up". And 16% of them erroneously indicated that it was correct, and six of them were sure of their answer. To the contrary, almost all students (82%) held a scientists' view that the statement was incorrect, and more than half of these students (47 of them) were sure of their answer. When asked to underline the incorrect word/phrase in the statement, 42 students recognised and underlined "build up" as an erroneous phrase. However, only 7 students wrote-in an acceptable phrase "converted to different forms" to correct the statement. The rest of the students still provided unacceptable phrases such as *used up* (23 students) and *lost* (7 students). As explained earlier, the word *lost* contradicts the principle of energy conservation, if there is no added explanation that heat energy is lost to the body during respiration.

4.2.3. Ideas relating to energy not being required when a body is at rest

This claim was tested in the statement *When you are asleep, your body does not require any energy because it is not active*. Very few students (7%) erroneously stated that the statement was correct. To the contrary, nearly all students (92%) correctly identified the statement as scientifically incorrect, and 71 of them were sure their response was correct. When asked to underline the word/phrase which makes the statement wrong, 47 students correctly underlined "does not require any energy because it is not active". Of the 47 students, 21 of them wrote in an acceptable phrase "does require energy as it is still active" and 8 other students wrote in another acceptable phrase "many body processes (e.g. respiration) still occur" to correct the statement. Most students in this study appeared to hold a scientifically acceptable view that the human body is active even at rest, and therefore energy is always required.

4.2.4. Ideas relating to energy being lost when an organisms is active

Slightly more than half of the students in the sample (59%) erroneously indicated that the statement *When living things are active, they lose energy* was correct, and 30 of them were sure of their answer. On the other hand, 40% of them exhibited a scientific view that the statement was incorrect, and more than half (20 of them) were sure of their answer. When asked to underline an incorrect word in the statement, 25 students correctly underlined the word "lose", with 7 students writing in the acceptable phrase "convert or transform energy into different forms". However, 10 of 25 students who underlined the word "lose" erroneously replaced it with an unacceptable phrase "used up".

The idea that *energy is lost* during activity in living organisms was documented by Solomon (1982). In everyday life experiences, people may well consider energy to be lost, and that the amount of energy decreases, especially during and after exercises. As a result, the scientific viewpoint that the amount of energy remains constant, despite the transformations that occur (i.e. energy conservation) does not seem to be applied in everyday experiences. According to the First Law of Thermodynamics (the law of conservation of energy), energy cannot be created or destroyed, but it can be converted from one form to another without any *loss;* any apparent loss of energy can be explained as the conversion of energy into some other form (Solomon *et al.,* 1993; Raven and Johnson, 1999). For example, during each energy conversion in living systems, some of the energy is used to drive the metabolic processes and some of it dissipates to the atmosphere in the form of heat. When talking about energy, the idea of energy being *lost* usually appears to be erroneous because it implies that energy is not conserved, although energy in the form of heat certainly *leaves* the body.

4.2.5. Inability to apply the energy conservation principle to biological situations

Although nearly all students (98%) correctly stated the energy conservation principle (energy cannot be created or destroyed) in test question 1, their ability to apply this concept to biological situations proved otherwise, as shown in Tables 3 & 4. The contradictory answers given to the closed statements could suggest that the students are unable to apply the idea of energy conservation. This situation may suggest that students could have rote-learned this principle or could have seen it in textbooks. Another source for this problem could be the language differences between science and everyday usage. Using phrases such as *used up*, *build up* or *lost* are not scientifically correct when talking about energy conservation.

The inability to apply the scientific idea of energy conservation in biological systems among students has also been identified by other researchers (e.g. Barak et al., 1997; Gayford, 1986; Goldring & Osborne, 1994; Kesidou & Duit, 1993; Kruger et al., 1992; Linjse, 1990; Liu et al, 2002; Solomon, 1985; Trumper, 1997; Warren, 1986). For instance, Barak et al (1997) conducted a study in which they found that majority of the students had difficulties in applying the law of energy conservation in a biological context. Other researchers such as Kesidou et al (1993) found that none of their 34 Grade Ten German students could apply the idea of energy conservation. Similarly, even teachers have been found to have this problem as documented by Kruger et al (1992) where majority of the answers teachers provided contradicted with the principle of energy conservation.

In light of students' inability to apply the concept of energy conservation, Warren (1986) explained that the *conservation of energy* is problematic because it implies *saving fuel* when used in everyday life and social understanding. In another explanation, Duit (1981) argued that energy conservation may not be intelligible to most learners because in everyday usage, energy is viewed to be "produced and consumed, but not conserved" (p. 292). The inability of students in this study to consistently apply this principle may suggest that students could have rote-learned this law or could have seen it in textbooks.

4.3. What happens to energy during metabolic processes in living organisms

Students' responses on what happens to energy during metabolism are in Table 5.

What happens to energy during metabolic processes	**% of Students**
Statements to do with energy being created or degraded	**55**
Scientifically acceptable statement	40
Energy is neither created nor destroyed	9
Scientifically unacceptable statements	6
Energy is created/made during processes (e.g. photosynthesis & respiration) in organisms	
Energy is degraded during processes	
Statements to do with energy used up & lost during processes	**37**
Scientifically unacceptable statements	
	27
Energy is used up during processes (e.g. respiration) in living organisms	10
Energy is lost during an activity (e.g. exercises) in organisms	
Statements to do with energy being transformed or transferred	**7**
Scientifically acceptable statement	7
Energy can be transformed or converted from one form to another	

Table 5. Students' responses on what happens to energy during metabolic processes

4.3.1. Ideas relating to energy being created or degraded in metabolic processes

Forty percent of the students correctly stated that energy is neither created nor destroyed during metabolic processes. However, these students did not go further to explain what happens to the energy - a situation which may suggest that they lack an understanding of energy transformation and transfer. On the other hand, some students erroneously stated that during metabolic processes, energy is created (9%) or degraded (6%).

In support of our findings, some researchers have documented that an erroneous idea of energy being *created* during biological processes persists among students. For instance, Eisten et al (1988) found that 3% of the biology majors and 4% of the non-biology majors provided answers which implied that energy is created during respiration. However, as pointed out earlier, it is possible that in the case of some teachers or learners these are not really erroneous ideas but imprecise use of language.

4.3.2. Ideas relating to energy being used up or lost during metabolic processes

Quite a large percentage of the students' (37%) provided responses which suggested that they erroneously believed energy is used up or lost during biological processes. That is, 27 % and 10% of the students erroneously wrote that energy is used up during processes and energy is lost during an activity in organisms, respectively. These findings add to the contradictory responses provided by these students to the closed-ended statements in Tables 3 and 4. Similar findings were documented in previous studies (e.g. Solomon, 1982; Linjse, 1990; Kesidou et al, 1993; Fetherston, 1999).

4.3.3. Ideas relating to energy conversion during metabolic processes

The idea of energy transformation or conversion is loosely understood by nearly all students in this study. That is, only 7% of the students correctly indicated that energy is transformed from one form to another during metabolic processes. Similarly, Mann (2003) also found that many students had poor understanding of energy conversion and transfer.

5. Implications for teaching and learning about energy conservation

The answers provided by students suggest that majority of them have an incomplete understanding of energy conservation in biological contexts. The question which then arises is: What should be done about the problems students have in understanding the biological-context energy conservation? There are several potential areas in which biology educators can get involved, if problems faced by students are to be minimised. First, it is important that teachers identify students' prior ideas before starting to teach energy conservation (e.g. Driver, et al, 1994; Fetherston, 1999; Solomon, 1982). This is because this concept has everyday life understandings which may conflict with those of science – a situation which can make students' responses scientifically incorrect. One possible way to do this is by using diagnostic strategies that uses every day and familiar contexts in order to help students understand the scientific viewpoints. By contrast, teaching energy conservation in terms that do not relate to familiar experiences may not be meaningful to learners – a situation which was triangulated in this study where students provided the textbook definition of energy conservation, but could not apply it to statements involving biological phenomena.

Second, we recommend that teachers explain why certain words such as *used up, built up, created,* or *lost* are unacceptable when talking about energy, since many students had problems with the energy conservation principle. It is hoped that if science teachers introduce and discuss the erroneous words or phrases, it may serve as a basis for alerting students to the problems involved in using them.

Third, there seemed to be a lack of understanding among many students that energy is not lost, but transformed to various forms during metabolic processes. Therefore, the concept of energy transformation could be one of the ideas which biology teachers could emphasize more when teaching about energy conservation. In this regard, we believe the use of the phrase energy is used up should be discouraged – instead we recommends the phrase *energy is transformed or transferred.* In addition other researchers such as Lee and Liu (2010) recommend that the teaching of energy and energy conservation be based on the knowledge integration approach (defined as students' knowledge and ability to elicit and connect scientifically normative and relevant ideas in explaining a scientific phenomenon or justifying their claim in a scientific problem), which takes into account the energy source, energy transformation, and energy conservation.

As stated by Gilbert *et al.,* (1982), one of the unintended learning outcomes which results when students' prior ideas are not appropriately dealt with, is that students stick to their own prior ideas in spite of teaching. This trend was evident in this study as students provided conflicting answers to the closed statements. Therefore, one practical approach to teach this concept is by providing students with a variety of situations, experiences and activities when teaching in order to overcome the usual conceptual reductionism. Since energy conservation principle is not intelligible to most learners, their understanding would be enhanced if the learning activities are based in contexts in which students construct their knowledge, particularly across science disciplines (i.e. biology, chemistry and physics) and everyday life contexts.

6. Recommendations for future research

Although identifying incorrect answers and ideas is a vital step in improving understanding, it is important that reasons for the incorrect ideas are understood. Thus, further research focussing on why students provide incorrect ideas is recommended. In particular, the researcher(s) would find out why students use phrases such as *used up, lost, built up, created*, when talking about energy conservation. Perhaps, this would lead to a step further in which the researcher could consider the extent to which everyday language and experiences interfere in the understanding of energy conservation. Secondly, some researchers (e.g. Lee, 2011) have advocated for a set of energy literacy to become the basis for further curriculum development and instructional design in schools. Therefore, research aimed at compiling what should constitute energy literacy is required.

7. Conclusion

Although energy conservation is considered an ease concept for students to recite as shown in our study, majority of the students have problems applying it to biological systems. For instance, our study revealed two major aspects. First, whilst nearly all students (98%) correctly stated the energy conservation principle (i.e. *energy cannot be created or destroyed to be correct),* majority of them could not apply it consistently to other statements testing the same concept. Second, many students erroneously indicated the energy is lost, used up, build up during metabolic processes in organisms. These findings suggest that even if students could state the energy conservation principle, they may in fact not have a conceptual understanding of the concept. However, one point to note is that some answers which were wrong could have been a reflection of language problems and not conceptual problems. Since energy is an important concept that concerns our daily life, students' mistakes in language usage can have detrimental influence on the scientific comprehension of the energy conservation principle. The language problem as a confounding variable in the diagnosis of students' understanding has been discussed by Clerk and Rutherford (2000, 715) when they stated that:

"Language problems do sometimes masquerade as misconceptions. This has serious implications for teaching. If a student is found to be answering questions incorrectly, it could be counter-productive to jump to conclusion that true misconceptions are held".

Therefore, the teaching and learning of energy conservation should be based on diagnosing students' language usage, and by using various contexts such as everyday life examples. Doing so would consequently ensure a complete understanding of the energy conservation principle in biological systems.

Author details

Vivien Mweene Chabalengula and Frackson Mumba
Southern Illinois University Carbondale, USA

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