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Students' conceptions about energy and the human body

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Abstract
Students' understanding of energy has been primarily within the domain of physics. This study sought to examine students' understanding of concepts relating to energy and the human body using pencil and paper questionnaires administered to 610 students in Years 8-12. From students' responses to the questionnaires, conceptual patterns were ascertained and organized under three assertions and several alternative conceptions, which varied with students' age, were identified. Alternative conceptions that have not been previously reported in the science education research literature were related to the nature and functions of carbohydrates and fats as well as physiological processes, like respiration and digestion.

Key words: *Energy, human body, biology, alternative conceptions, secondary school, energy conversions, cellular processes.*

Introduction

For more that four decades, studies have documented understanding of concepts in various science domains among learners whose ages ranged from pre-school to university undergraduates and practicing teachers. These studies have been mainly concerned with learners' misconceptions, preconceptions or alternative conceptions and conceptual growth. Duit (2009) has recorded some 8400 studies across all areas of scientific learning, of which studies related to energy were mainly in the area of physics (recent examples include Domenech et al., 2007; Liu & McKeough, 2005; Papadouris, Constantinou & Kyratsi, 2008; Gyberg & Lee, 2010), with very few studies involving energy and the human body. Most of these latter studies have involved the fields of general respiration (Lavoie, 1997; Simpson & Arnold, 1982), sight and the path of light (Boyes & Stanisstreet, 1991; Osborne, Black & Meadows, & Smith, 1993), hearing (Boyes & Stanisstreet, 1991), and food as an energy source (Arzi, 1988; Duit & Haeussler, 1994; Francis & Hill, 1992). Other studies have examined students' understanding of energy flow in the context of food chains, photosynthesis and respiration (Lin & Hu, 2003). The study reported in this article endeavours to rectify this omission, albeit to a limited extent by investigating students' conceptions relating to energy and the human body.

Gayford (1986) observed that many biology students do not study physical science, and in particular that the concept of energy is rarely covered adequately in biology classes. As a result, students find the concept of energy difficult to comprehend. Hence most students bring with them to the classroom alternative conceptions that were formed earlier in their studies or everyday experiences. In the science classes in the State where this study was conducted, the concept of energy is studied overtly in physics. In biology, energy is introduced mainly with reference to photosynthesis, and is also covered briefly in respiration as a source of energy and as energy transfer in a biological community via food webs and bio-pyramids.

Some authors have concerned themselves with the differences between the meanings of words in different fields of science (Gayford, 1986; Kirkwood, Carr, & McChesney, 1986; Solomon, 1984). For example, biology teachers refer to the 'flow' of energy from one body to another while physics teachers use the 'transfer' of energy (Barak, Gorodetsky & Chipman, 1997; Gayford, 1986). Similarly, Kirkwood *et al.* (1986) suggest that "differing disciplines hold differing concepts of energy" (p. 178) and that these differences are related to the academic backgrounds, with biology teachers (or chemistry teachers) views of the energy concept unlikely to be identical to that of the physics teacher.

Energy is an all-pervasive phenomenon not only in science but also in everyday living as humans are continually exposed to its various forms. As a consequence of this common usage, energy has developed a whole set of meanings in everyday life that are in conflict with the meanings assigned to these words by science (Kruger, 1990; Warren, 1983). From their everyday experiences, people develop some of their preconceptions of energy; for example, we hear of 'burning energy', 'using up energy', 'conserving energy', 'wasting energy', 'saving energy' and numerous other terms. These everyday meanings lead to conceptions which are scientifically naive and may be in conflict with those held by scientists (Duit, 1987; Lijnse, 1990; Watts 1983). It is important that instructors cater for these language differences and more importantly the differences between the everyday and scientific meanings of words and terms when interpreting data obtained from students (Linsje, 1990; Mann, 2003; Solomon, 1984).

The purpose of this study was to identify students' conceptions of energy with regards to the human body across all secondary school classes using a modified two-tier pencil and paper test. Subsequently, a number of items were designed to identify students' conceptions of energy and the human body that have the advantage of the items themselves do not prompt or lead students to making their commitment.

Methodology

Development of test items

The construction of the set of items followed the process originally described by Treagust (1995) that involved delineating the area of study by compiling a set of propositional content knowledge statements. These statements were checked for accuracy by three teachers of Human Biology to verify that the propositions did cover the main areas under investigation. The tests items were developed around the major problem areas relating to energy and the human body identified in the literature, namely: (1) the energy types in food, (2) the sources of energy for the human body, (3) the processes of vision, hearing and respiration, (4) energy conversions and transfers within the body, and (5) temperature regulation. From a search of the extant literature, and through conducting a series of interviews and administering two open-ended essays, several problem areas within the area of energy and the human body were identified. These problem areas were then used to develop a set of 26 statements that were subsequently modified to form the stems of the questionnaire items. A specification grid was then constructed to ensure that the 26 items covered the relevant sections of this topic.

The interviews were based on the model of interviews-about-events (Carr, 1996). In this study a series of four collages were presented to the interviewees with each collage relating to a different aspect of energy and the human body, including the intake of food, exercise, cooling down processes and weight gain and loss. Each collage was accompanied by an opening question that was to ensure both interviewee and interviewer was discussing the same feature in the collage. A series of questions based on each collage, designed to identify student conceptions relating to the issue of the collage, were used. The responses were used in developing the questionnaire.

Questionnaire structure and development

The two-tier multiple-choice format was modified by Mann (2003) to create an item which had a stem similar to a multiple-choice item but with the first tier involving an agreement or not with that stem. The second tier of the item required students to give a reason for their agreement (see Figure 1 for an example). The reasons provided by students were subsequently used as the data source for reporting the findings of this study.

Example of an item

The energy in the food we eat is found in tiny bundles or packets found in between the food particles.

AGREE / DISAGREE

Reason:………………………………………………………………………….......

…………………………………………………………………………………………

Figure 1: Sample of item used in the two questionnaires

The final set of 26 items was divided into two different questionnaires each titled "*What do you know about Energy and Your Body? Questionnaire 1*" (14 items) and *"What do you know about Energy and Your Body? Questionnaire 2"* (13 items). One item was identical in both questionnaires and was used to cross-check consistency of students' reasons in both instances. An example of an item is in Figure 2.

2.) Different food groups are used as energy sources by the human body and these groups have different types of energy and different amounts of energy.

TRUE/FALSE

A. each food has the same type of energy and the same amounts of this energy
B. different food groups have different amounts of energy with the same type of energy in foods
C. each food has a number of different types of energy in it and each of these is in different amounts
D. we carry out different types of activities and so these activities need different types of energy to occur
E. ____

Figure 2. Item 2 as an example of the items of the questionnaire

Student sample

The two questionnaires were administered during classroom instruction time to 610 students in Years 8 to 12 (aged 13-17 years old), with approximately the same numbers of students attempting each questionnaire. The student sample was selected from a middle-income socio-economic suburb as indicated by the Education Department and based on the national census data. All students spoke English as their first language.

Data analysis

The data collected from both questionnaires were collated using the reasons given by the students as support for their agreement or disagreement with the statements for each item. Patterns within the data set were ascertained and organized under three assertions (Erickson, 1998). It is not possible in many cases to accurately provide the numbers of students as a percentage of any particular year level because the reasons used as evidence for an assertion came from a number of items and so in most cases we have used the total number of responses that provided the evidence. For each assertion, supporting evidence was identified to indicate the foundation for the assertion.

Results

Assertion 1: Students' perceptions of energy availability in food varied according to their perception of the type of food that was eaten.
Almost all students in this study (about 90%) agreed that food supplied energy. For the students who disagreed with the statement, sugars and carbohydrates (sometimes as separate chemical families) were the most frequently chosen sources of energy, with vitamins and minerals given only by a minority of students. Sixty students (about 10%) from all year levels also claimed fats as a source of energy while a smaller sub-group indicated that fats were a poor source of energy.

Food as the only source of energy for the body was specified by 20 students (with 7 from Year 8), while 74 students over the whole cohort stated that energy was one of a number of sources, with oxygen and sleep being nominated as two of the other energy sources. Students who stated that food was the only source of energy for the body also indicated oxygen had no role in obtaining energy at all by claiming that air is involved in breathing to keep us alive. Approximately 59% of all respondents indicated that different foods had different amounts of energy with approximately the same percentage of students in each year level making this claim (Table 1). That the quantity of energy in the food depends upon the type and quantity of each food group present in the food eaten was reflected in the following responses: *"chocolate gives you lots of energy while other foods like vegetables don't"*, and *"it depends upon how much sugar, Carbohydrates etc are in the food as some ingredients have higher energy contents than others*". These quantities of energy were perceived to determine the amount of food needed to meet the energy requirements of the individual.

Table 1. Year cohort related views of the energy quantities in foods.

Amount of energy in all food types	Percentage of students				
	Year 8	Year 9	Year 10	Year 11	Year 12
Different amount	19.5	16.1	15.1	9.4	14.5
Same amount	3.2	2.9	2.5	0.6	2.2

However, a small number of students (n = 22) claimed that all food has the same amount of energy and elaborated on their claim by stating that some energy is available for absorption and so is used by the body while the rest of the energy in food is either excess or unavailable. A number of students (n = 72) claimed that excess energy is excreted. The value and role of fats changed with the respondents' age. Some respondents in all year levels expressed the notion that all energy in food was absorbed and if not used quickly it was converted into fats. Many Year 8 students thought that once energy was stored as fats it was locked away and no longer available for use. In later year levels students expressed the notion that all energy in food was absorbed and if not used quickly it was converted into fats for use later (after other energy sources were depleted).

A relatively small number of students (n = 24), mainly among the older students, indicated that there was only one form of energy in food as illustrated by the reason, *"there is no different types of energy just less or more energy. The energy in a 'Snickers' (a chocolate and nut bar) is less or more that the energy in a red jelly but it is not a different type"* compared to a large number (n =198) who said that there is a variety of energy types in food. This belief is illustrated in the examples, *"all parts of the body need different kinds of energy to make them work", "different foods and ingredients have different types of energy"* and *"certain foods carry different kinds of energy"*. Several of these students stated that to get all these types of energy, the body needed to ingest a variety of foods.

Students defined useful or good energy as energy we used or energy which allowed us to carry out an activity, as illustrated by *"it will be useful if you are active, not useful* *if you're not"*, while other students said too much energy is bad for you as you become hyperactive *"because if you have too much energy you might go hyper"*. A group of students said that some energy, for example from sugars, was easily or readily available and so readily used and therefore valuable, while the energy in some food was hard or impossible to use and so was useless, for example, *"you only utilise the useful energy. The rest is converted into and stored as fat"*, and *"if we want lots of energy… you eat lots of carbohydrates. But if you want a quick burst… you eat sugary foods"*. In lower years, students stated that they only absorbed the useful energy or what they would need in the immediate future with the rest excreted.

One other interpretation of useful energy occurred, where useful energy was taken to mean the speed at which the energy was available for use. Many older students (Year 10 and higher) indicated that all energy was useful even if not used immediately, as it was stored as fat for later use.

The way students perceived the usefulness of energy changed along an age-based continuum from being useful only if the energy is used immediately (Years 8 and 9) through to all energy being useful (Figure 3) either when it is used immediately or stored for later use (Years 10 to 12). The only appearance of the terms 'good' and 'bad' when referring to energy occurred in Year 8 and was defined in a similar fashion to the way that 'useful and useless' energy was used by other students.

The meaning of the term 'energy value' in food had a number of connotations with two being predominant, namely, quantity and quality. The value of the energy in food was not specified in any of the students' responses to the items referring to energy and food but was indicated in the responses to other items.

Year 8--Year 12
Useful only if used immediately   All useful as can store in fats
(little stored and lots excreted)   (lots stored and little excreted)

Figure 3: Diagram showing the continuum of energy usefulness with student age.

The data to support Assertion 1 indicated a general lack of knowledge about energy in food other than that food is required as an energy source and that different foods possess different quantities of energy. Within the sample studied, there was confusion over the role of the different food groups with respect to energy and what happens to the food once it has been ingested. Some students thought energy was only absorbed if it is needed, others that if energy is absorbed the excess is stored as fat and is never used, while still other students thought that the fat may be used when other energy in the body has become depleted. A number of students on the other hand had the notion that there are a number of types of energy in food and that different food groups or ingredients have these energy types. This latter notion changed with the age of the students as more students in Years 10 - 12 held the conception that there is a single energy type in food; only a few students in Year 12 held the notion of bond energy or that the energy in food is in the chemical bonds.

Assertion 2: There is limited understanding of energy use, energy conversions and energy transfers in the body

The lack of knowledge on the usefulness of energy would appear to have its roots in the students' knowledge about the process of respiration and its converting food energy into useable energy for the cell. Few students indicated they knew anything about the role of respiration in energy conversions and transfers (see Table 2). If this knowledge of respiration was present and understood, students' understanding of the fate of food would be better known because they are linked. As the students' age increased, so did their knowledge of respiration and its position in the formation of useable energy - but still remained rudimentary. No students in Years 8, 9 or 10 indicated any knowledge of energy and respiration while students in Years 11 and 12 gave responses with more details; some students indicated a rudimentary knowledge of respiration being involved in energy transformations.

Table 2. Year-related views on aspects of respiration as percentage of total respondents

Functions of respiration	Year 8	Year 9	Year 10	Year 11	Year 12
Role of respiration	0%	31.5%	17.5%	36.3%	66.7%
involves energy conversions	27/0	19/6	25/7	22/8	9/6
Respiration involves	3.6%	53.8%	15.3%	61.1%	83.3%
conversion of sugars into useful energy	25/9	13/7	26/4	18/11	12/10
Respiration involves	19%	11.7%	4.3%	31.5%	61.5%
conversion of fats into useful energy	21/4	17/2	23/1	19/6	13/8
Respiration converts energy	3.7%	47.3%	20%	54.5%	19.2%
in food into useable energy	27/1	19/9	25/5	22/12	26/5
Respiration involves oxygen	0%	15.6%	9.2%	48.9%	3%
	76/0	51/8	76/7	49/24	33/10

Note: The fractional number at the bottom of each box (for example 27/0) is the number of respondents (27) who gave a response fitting this category and the second smaller number (0) is the number of students who gave a valid reason.

A small number of students claimed respiration uses energy and is not involved in the production of useable energy when they gave reasons such as, *"respiration uses energy, not creates it"*, and *"respiration is not the process of making energy"*. Both of these reasons might be a result of respiration being seen as the process of breathing, in which case they would be valid reasons for the items. Without this knowledge of cellular respiration (indicated in Table 2) and its function to produce ATP or the 'universal energy molecule', it is understandable that students would not know about many of the possible energy conversions which occur in the body and so they are likely to come to the conclusion that there was good and bad energy or energy that was useable or not useable.

A problem with the use of the term 'respiration' and not 'cellular respiration' was that 10% of all students viewed respiration as being synonymous with breathing, and therefore respiration was not seen to be involved in energy production. From the population of 610 students, only five Year 11 students and one Year 12 student used the term 'cellular respiration' to make their response specific.

A few students (n = 6) stated that food was burnt with oxygen and this released the useful energy, but showed no understanding of the actual process of respiration. During a series of interviews of students in Years 8–10 conducted to reveal the meaning of a number of terms including the word 'burnt', students were found to hold a dual meaning of the word. The first meaning was a situation similar to that of the burning of paper in the presence of air and the second was a substitute for oxidation as occurred during respiration. While all year groups displayed poor understanding of the role of respiration, the role of oxygen in energy conversions during respiration was also poorly understood.

A small number of Years 8, 9 and 10 students (n = 35) suggested that oxygen was an energy source or was actually energy, as in the example, *"we get energy from oxygen"*, while many younger students indicated that respiration did not involve oxygen. In Years 9-12, this problem was less evident as more students knew oxygen as being involved in respiration. A number of respondents stated that food was burnt with air/oxygen to release useable energy, a similar finding to Arzi (1988) and Barak *et al.* (1997). Despite these responses, few students appeared to know any detail about the processes involving respiration and energy transfer.

With limited understanding of the process of respiration, it is understandable that students' comprehension of the role of sugars, carbohydrates, proteins and lipids in energy production was unclear. Few students made a connection between these food groups and respiration and energy. Only students in Years 8 and 9 thought that people obtained energy from food and that energy was released by the process of digestion with only the energy which was needed by the body being absorbed into the body or blood. However, students in Years 10 to12 indicated that the body absorbs all food energy and stores the excess energy as fat which can then be utilized at a later time as a source of energy. The role of fats as an energy source has been discussed in Assertion 1, with younger respondents indicating fats were not an energy source or that it became locked away. This notion decreased with age and became more aligned to reality.

A number of other sources of energy were found in the responses. These included students in Years 8 (n = 10), 9 (n = 5) and 10 (n = 10) suggesting that sleep was an energy source, e.g. *"our body rests and when we wake up we have produced energy to use"*, or that sleep restored or replenished the energy supply of the body, e.g. *"because sleep rests our body and recharges our body"*. Eight students stated that the body produced more energy when asleep than was used when asleep, for example, *"our body processes food when we sleep but we don't consume energy"*, and this excess energy restores our body's energy levels. This notion is in contrast to several students who claimed that we still use energy when asleep but do not replace that energy, or a small group of students in Years 8 to 10 (n = 10) who stated that they do not use energy when asleep.

Responses to the three items relating to the ear, the eye and the bicycle which examined energy conversions by the body showed that few students knew about energy conversions and transfers which are carried out within and by these body regions. Despite energy conversions and transfers being taught in Year 9 along with the functions of the eye and ear, students appear not to know that energy is converted into other forms by the body. These students also appeared not to know how the ear or eye works to facilitate energy conversions. And a very small number of students (n = 8) reasoned that sound and light were not energy. Some students (n = 30) indicated some knowledge of the vision process which was rudimentary and inaccurate when they stated that the light from a tree went from the object through the eye to the brain without any processing by the eye and that the brain directly translated the light energy. A similar finding applied to the role of the ear and hearing where students claimed that the brain translated the sound to enable people to hear the object (n = 58). Only six students indicated that the eye or ear converted light or sound energy into nervous impulses, which the brain could then translate.

Further evidence of energy conversions and transfers not being known, understood and/or applied, was reflected in the responses to the items on the bicycle as an energy transfer system. A minority of students indicated energy was transferred to the bicycle from the rider while 80 students stated that energy was not transferred. Further, a number of Year 8 to Year 10 students claimed energy transfer could not happen as the bicycle was inanimate and therefore could not possess energy, making claims such as, *"the bike is not living so it can't get the energy"*. Other researchers have reported this anthropocentric view of energy (Duit & Haeussler, 1994; Trumper, 1991).

A minority of Year 8 students stated that when energy is used it is lost or destroyed and so is unavailable for further use. Another reason for humans not transferring energy to the bicycle was that the bicycle has its own energy and this energy which makes the bicycle move. There was general agreement that the bicycle needed a person to expend energy to make it move. However, 58 students who made this claim also made no mention of energy transfer to the bicycle, while 78 students did indicate that energy was transferred to the bicycle in the process of making the bicycle move. Most Year 11 and 12 students expressed the idea that using legs to move the pedals resulted in the transfer of energy to the bicycle via the pedals and this resulted in the bicycle moving forward. While four of the Year 12 students also discussed the role of kinetic energy in the energy conversions, e.g. *"we transfer kinetic energy from our legs to the pedals which turns the crank which in turn starts the wheel spinning"*.

With no knowledge of the processes or chemistry of respiration and that energy is in the bonds of compounds (i.e., location of energy in foods as found in Item 1 which related to bundles of energy in food), it is not surprising that students had no idea of how body heat, and hence body temperature was derived from chemical reactions.

The role of sweat leaving the skin via evaporation and thus cooling the body was poorly understood as only two students indicated that the process of evaporation led to a cooling effect and there was no hint of the latent heat of evaporation in any of the reasons given. While no student stated that heat is converted into sweat as found by Westbrook and Marek (1992), many students stated that heat energy (or particles if the particulate notion was used) went into the sweat and as the sweat left the body the heat accompanied it, for example, *"when sweat is evaporated, heat is taken out with the sweat"*.

Two other reasons relating to cooling were that air coming in contact with the sweat somehow cooled the sweat down, as in the examples *"the wind cools us down"*, and *"when air blows over us it makes us feel cooler"*, and sweat has no effect or influence in cooling the body, e.g. *"…sweating doesn't make us cool"*, *"when I sweat I still feel just as hot*".

Assertion 3: Students view energy when involved with the body as existing in a variety of types and existing in packets.

Students across all Year levels (n = 198), ranging from 20% (Year 12) to 60% (Year 8) of each year cohort, indicated energy in food comes in a range of types or varieties, but what these types of energy were was not revealed in the written responses such as *"because there is loads of types of sources with different uses"*. This response expressed the idea that the energy in food is found in a variety of forms, which the body uses to carry out its various functions and thus necessitating a variety of foods to supply the variety of energy types required, e.g. *"food gives all types of energy"* or *"the body required a variety of different energy types to perform different functions"* or *"Different food has different energy types"*, and *"a good balanced diet contains all the types of energy we need"*. Only 13 students in Years 8 to 10 and six from Years 11 and 12 indicated that there was only one type of energy in food.

The fact that students suggested that energy in food comes as a number of different types is a further indication that students in this study do not have a scientifically acceptable notion of what energy is and the role of respiration in the body. That is, glucose, carbohydrates, proteins and lipids are energy sources with energy being transferred during respiration to ATP or the 'universal energy molecule'. This finding supports work in this area carried out by researchers such as Arzi (1988), Barak *et al.* (1997) and Duit and Haeussler (1994).

A decreasing number in each year cohort held the view that energy exists in packets or bundles found between the food particles rather than in the food molecule itself

[Year 8 (33.6%), Year 9 (32%), Year 10 (23.7%), Year 11 (17.6%) and Year 12 (22.7%)]. The reasons given did not specify why the packets were not inside the food particles/molecules e.g. *"because our body releases tiny bundles of energy found between the food particles into our blood"* or that energy is released from the food when it is digested, (*" because the energy in the food is changed into workable energy through the process of digestion).* This latter suggestion was from those students who agreed with the idea of energy as existing in bundles. The students who stated energy was in the food particles or molecules gave no specific location for that energy while only two Year 12 students indicated the energy in foods was found in the chemical bonds.

The idea of packets of energy fits in with the notions that there are different types of energy, different types of energy are found in different foods, digestion releases energy, energy can be useful and only useful energy is absorbed. If energy is in particles then the particles can be different and be unique to each food type, energy type and energy use. The particulate nature of energy can fruitfully explain many of the concepts held by students with regard to energy and the body, for example, sweat carrying heat energy along with it, or the absorption of useful energy only from food or the types of energy in food. The notion of a particle of oxygen being a type of energy and since light and sound are non-particulate they are not energy also supports in the student's mind that energy is a concrete material and so is particulate. This finding is further evidence that supports work reported by Trumper (1997), Chi, Slotta and de Leeuw (1994) and Duit (1984) who all found that students thought energy was substance-like. The notions of energy in packets, oxygen as a type of energy and light and sound not being energy declined with age but at varying rates for each of these separate notions as shown in Table 3.

Table 3: Conceptions of energy held by students as percentage of year cohort

Students' conceptions of energy	Percentage of students				
	Year 8	Year 9	Year 10	Year 11	Year 12
Packets of energy	29.8	14.6	13.6	9.1	18.2
Oxygen as type of energy	17.8	10.5	13.6	9.1	18.2
Light or sound is not energy	0	0	1.4	2.2	6.8
One type of energy in food	4	3.5	3.5	2.2	9.1

Other student's conceptions identified in this study

Energy and the human body is a very broad area of study that involves several different aspects of energy. So, it is not surprising that other researchers have reported several of the energy conceptions held by students identified in this study. Although several of these findings support the findings of previously reported investigations into energy in settings other than the human body, it would appear that these findings are transferable to the human body situation. In addition to previous research findings, several student conceptions have been identified in this study that have not been presented elsewhere. These alternative conceptions are briefly presented here without further discussion.

Sugars and carbohydrates are seen as being different and the carbohydrate food group does not include sugar and visa versa as illustrated in the statement, *"food contains carbohydrates, sugars, fats etc…"*. Both of these substances are energy sources but with different speeds of availability for use.

All energy receiving organs and tissues of the body such as the skin, ears and eyes while receiving energy from the environment also need energy so they can function. This type of response was given by several students from all year groups and is illustrated by *"you need energy in our eyes, … and our lungs or else they wouldn't work"*, and*" they all need energy to function properly"*.

A range of conceptions about the fats containing energy and its availability for later use was found, varying from energy being readily available to energy being locked away permanently once incorporated into fat. This differs from the previously reported notion that fat is a useable energy store site for excess absorbed energy (Baird *et al.* 1987) with responses such as, *"fat is not a useful source of energy for people"*, *"…because not all fats break down and your body can't use it"*

As mentioned in Assertion 2, the role of the eye and ear in converting energy is not revealed in any responses and is similar to the findings of Guesne (1985), Osborne *et al*. (1993) and Collis *et al*. (1998) who found light goes through the eye to the brain where it is interpreted. Similar finds related to sound and the ear. These findings show a limited understanding of the role that the eye plays in seeing or the ear in hearing in converting light into nervous impulses, *"Sound is only a vibration which is decoded in the brain"*.

A finding that also emerged in this study was that heat is removed form the body with seat carrying it in the water as it leaves the body and has been reported by Westbrook and Marek (1992); other conceptions included sweat having no effect on cooling the body. One conception common across all years was that sweat cools the body down because air or wind came in contact with the sweat or that contact of the wind or air which has the cooling effect (*"while this is happening the air or wind blows on our skin and cools us down"*.)

Conclusion and recommendations

The major problem areas that were identified relating to energy and the human body were: (1) the energy types in food, (2) the sources of energy for the human body, (3) the processes of vision, hearing and respiration, (4) energy conversions and transfers within the body, and (5) temperature regulation, were all very poorly understood.

From these problem areas, three assertions were derived: (1) Students' perceptions of energy availability in food varied according to their perception of the type of food eaten; (2) There is limited understanding of energy use, conversions and transfers in the body; and (3) Students view energy when involved with the body as being in a variety of types and existing in packets.

The study has revealed a number of conceptions held by students that were similar to those previously identified by other researchers. For example, the particulate nature of energy, useful or 'not useful' energy in food, energy obtained from air or oxygen, energy not being conserved when used, and fat not used as a source of energy by the body. New findings presented, were (1) carbohydrates are different to sugars, (2) energy is needed for organs to function, (3) fat locks away energy for varying periods of time, (4) excess energy is not absorbed but excreted, (5) the eye and ear do not convert energy but merely relay it directly to the brain where it is interpreted, (6) sweat cools the body because air or wind comes in contact with it (not through evaporation), and (7) objects do not need energy to move but only to get the movement started. In this research, we have demonstrated that these conceptions are common across different age groups and changes occur as students are exposed to more phenomena and examples relating to energy.

From these findings it is recommended that teachers present energy in a variety of situations and not just in a physics context because energy concepts are applicable across a number of learning domains. This approach will facilitate the need for students to be exposed to the various roles and the numerous aspects of energy in relation to their own body's functioning. In so doing, teachers will make the class-work more relevant to students and broaden their learning experiences. At the same time, students will be exposed to the dual nature of the language used in science and in everyday life and so become more adept at communicating effectively at both levels.

Further research into the way conceptions develop within a class situation and the possible pathways followed by members of a class need to be investigated so that teachers can identify students' knowledge in the process of concept development. Based on this knowledge, teachers can adjust learning experiences to direct or guide students in ways that they may develop more scientifically acceptable conceptions.

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