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Ghanaian primary school pupils' conceptual framework of energy

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Abstract

This study investigated the conceptual framework of pupils on the topic '***energy***' which is one of the popular topics taught in the Basic Schools in Ghana. A teaching model comprising teaching and learning activities depicting concepts of energy was tested on some primary school pupils. The study was based on a structured questionnaire and a test designed and served on some Ghanaian primary school pupils (N=186) in the age range of 11 and 12 years. The results of the tests were correlated for pupils' performances on conceptual –type and algorithmic-type questions by a Chi square test. The results showed that there exists statistically significant difference between conceptually oriented and algorithmic pupils at the p= 0.10 confidence level. It came to light that majority of pupils depended on rote learning than on learning for conceptual understanding. Recommendations are, therefore, made for improving the teaching and learning of science in the primary schools.

Keywords: Basic Schools, Basic education Certificate Examination, misconceptions, perception of energy, conceptual change, high order cognitive skills, algorithmic and conceptual-type test, rote memory skills.

1.0 **Introduction to the study**

Over the past three decades, considerable volume of research has been generated on primary, secondary and tertiary students' understanding of concepts in science. Case studies have revealed that the students' conceptual understanding are often inconsistent with scientific thinking which has variously been referred to as 'misconceptions', children' science, 'alternative frameworks', 'preconceptions', 'alternative conceptions' and 'ideas' (Ebenezer & Connor 1998). In this study, the term 'alternative conception' will refer to a conception that differs significantly from that which is commonly used by the scientific community, i.e., conceptions that arc wrong from the curricular point of view and the teacher would attempt to correct the children's misconceptions to achieve the scientists' conceptions. The complexities involved in the concept of energy of moving bodies may not readily be available in children's perceptual experience. There is therefore the need for well-thought out teaching strategies to make unfamiliar concepts familiar to children (Christidou & Koulaidis 1997). The aim of this research was focused on pupils' perception of energy with regard to "energy as means of causing movement", "availability of energy in living things" and "effects of energy like burning".

Learners at all ages hold a wide variety of misconceptions described by Zoller (1996) as "scientifically faulty knowledge structures". In recent years the Ghanaian publishing arena has experienced a proliferation of booklets in various subjects including science. This rapid expansion in the book industry has come with the disadvantage of inexperienced writers who, for monetary gains, are putting un-refereed science books onto the market. Most of these booklets contain misconceptions and inaccurate factual scientific knowledge that are learnt by pupils. As it is very difficult to distinguish between misconceptions and alternatives to science concepts, experienced science teachers are needed to explain such knowledge to pupils. The Ghanaian educational system, however, places the less experienced teachers in the basic schools while the more experienced ones are placed in the senior high schools. Thus pupils tend to pick a lot of misconceptions and misunderstandings in science from the early ages. The only hope for conceptual change lies in the assertion of some authors (Griffith, Thorney, Cooke & Normore 1988) that misconceptions are quite amenable to change as they might not have been firmly rooted, especially among primary school pupils.

This study is premised on the constructivists' view that: (1) learners' conceptions of natural phenomena, to a large extent are shaped by their every day experiences; (2) learning involves the construction of meanings; (3) learners' existing knowledge and experience affect the meanings they construct about phenomena; (4) different learners possess different knowledge bases and so are likely to construct different meanings from the same scientific information; (5) there are discernible patterns in meanings which learners construct due to shared experiences within and outside the classroom (Aikenhead & Jegede 1999; Ebenezer & Connor 1998; Gunstone & White 2000).

The complex and abstract nature of many scientific concepts, e.g., heat and heat transfer, magnetism and electricity are matters warranting a closer investigation. This is frequently the case in science education where young learners have problems in studying energy, since learners have had prior experiences about many topics in science. For example, they have experienced forces (e.g., magnetism), living things (e.g., pets and house plants), solar system effects (e.g., day and night and eclipses), chemical change (e.g., burning), and a host of others. Learners even make decisions based on these encounters, and for the same reason they would not touch fire, a hot plate, an exposed live wire, look directly at the sun and so on. However, many science teachers find that their learners have some difficulty in coping with the concepts associated with these common phenomena. While it may be easy to spot the effects of the phenomena involving these concepts, it is not easy, even for adults, to decipher how they are brought about (Jones & Ingham 1994).

The specialized way in which we use these everyday terms: energy, magnet, electricity, etc., in school science create real curricular and instructional challenges beyond what is often realized. Many findings from research on alternative conceptions relating to these concepts have shown how the way scientific concepts are presented and in what context they are discussed can be critical to learning. Furthermore, contrary to the general view that alternative conceptions are the result of poor teaching, research has shown that learners' alternative conceptions have arisen largely from common daily experiences and the interpretations of these experiences in terms of their socio-cultural environment (Aikenhead & Jegede 1999; Gunstone & White 2000). However, interesting as the issue of science and culture is, it is not the focus of this study.

A review of the existing literature indicates that the interest and enthusiasm shown by primary school learners towards science do not persist for long. In fact, a marked decline both in their interest and performance are already noticeable by the time they complete primary school education (Wood 1999). This phenomenon may not be unrelated to various social pressures experienced by learners as they grow as well as the enormous increment and complexity of what is to be learned. However, an exploration of these socio-cultural factors is also not the focus of this study.

Science education standards documents generally agree on what all learners should know and be able to do in science in order to become educated members of society (American Association for the Advancement of Science (AAAS) 1993; Lee & Paik 2000; National Research Council (NRC) 1996; Raizen 1998). These documents define science in a comprehensive manner that includes not only scientific understanding and inquiry, but also how science is related to personal, social, cultural, economic, and historical perspectives. As a study of natural phenomena in everyday life, science offers significant learning opportunities. In particular, hands-on science can promote learner engagement, interest, curiosity, and excitement in learning about natural phenomena (NRC 2000). For learners who have limited prior experience in science, hands-on science offers the context for life experience in the classroom setting as well as enrichment for further learning. Hands-on science also reduces the burden of language use, thus allowing learners to focus on science content. For learners with limited exposure to literacy, concrete experiences build the basis for complex and abstract thinking. As learners relate their prior knowledge and experience to newly constructed knowledge, science learning becomes meaningful and relevant.

Studies on alternative conceptions have shown that learners across cultures: (1) hold a multiplicity of ideas about various natural phenomena based largely on their beliefs, and commonsensical worldviews; (2) may adhere to beliefs which may not necessarily be the product of poor instruction but have arisen from their experiences with diverse phenomena and interpretations of such experiences; (3) may hold beliefs which persist in the face of contrary instruction; (4) tend to demonstrate more alternative conceptions on familiar topics than abstract and unfamiliar topics; and (5) seem to construct patterns of meanings according to the prevailing worldviews in their socio-cultural environment (Ogunniyi & Fakudze 2003; Palmer 1998).

In view of these findings, it can be assumed that a good instruction would: (l) check learners' construction of meanings before and after an instructional episode; (2) clarify the contexts in which beliefs are appropriate; (3.) ensure that discussions on learners' beliefs are carried out not only on familiar topics but also those that are abstract or remote from their daily experiences; (4) make efforts to render complex subject matter in a simple and comprehensive manner; and (5) as much as possible introduce topics that warrant the use of unfamiliar words or common words used in a specialized way in the most sensible manner (Ogunniyi 2000). The idea here is that familiarizing learners with a topic and using a robust diagnostic assessment and a flexible but effective remedial instruction approach are critical to efforts directed at ameliorating alternative conceptions held by learners on various science concepts. This research reports the findings of a study, underpinned by a diagnostic-remedial instructional approach, which seeks to find out whether or not Ghanaian upper school primary learners also exhibit similar characteristics with respect to the concept of energy.

2.0 **Statement of the problem**

Science and technology form the basis for inventions, for manufacturing and for simple logical thinking and action. The rationale for the teaching of science in Ghana is to train young men and women in the sciences as a means of attaining scientific and technological literacy and also provide the young people with the interest and inclination toward the pursuit of scientific work (Ministry of Education (MOE), 2012). One major constraint facing Education in Ghana is poor teaching that has resulted in an unacceptable performance of pupils at the basic education level.

Analysis of the Basic Education Certificate Examination (BECE) results from 2000 in the Central and Volta Regions of Ghana show that, about 50 Junior High Schools (JHSs) in the rural areas in the Central Region managed a score level of zero percent in the examination. Also, in the Volta Region, out of the 2,313 students who sat for the examination, only 81 pupils obtained aggregate six (i.e., pupils scoring 75% and above in six subjects at the BECE). What this means is that all the nine years of the Basic Education Course and all the sweat and toil and expenditure involved have been in vain. The 2000 BECE results have given vivid and lucid illustration of the consistently poor level of performance in the Regions. In the Akuapem North schools, for example, out of a total of 1,963 pupils who sat for the BECE in 2002, only 11 had aggregate six and five schools had zero percent (Quaicoe 2003). Also, analysis of the results of an international study involving 46 countries, in which Stages 4 and 8 pupils were assessed in Mathematics and Science, Ghana was 45th in position with a performance significantly below the international benchmarks set, and significantly below the international mean (Anamuah-Mensah, Mereku & Asabere-Ameyaw 2004). The picture painted here suggests that there is a problem in the teaching and learning of science at the Basic Education level. These challenges suggest a scrutiny of the learning difficulties of pupils in science as well as the adoption of appropriate intervention strategies that will enhance learners' understanding of the science concepts being taught.

One of the main topics in the integrated primary science syllabus is ***energy***. Energy is an appropriate topic for detailed consideration, because it has not been very easy to develop a comprehensive strategy (Dobson 1987) for the teaching of the concept. Also, some researchers (e.g., Carr *et al.* 1994), believe that 'energy' should be introduced in a simple manner at an early age in the learning process. A plethora of studies has shown that despite the prevalence of energy in the science curriculum, learners at all levels of the educational system often hold invalid conceptions of this common term with specialized meaning in science. If learners hold invalid conceptions or misconceptions (Ebenezer and Connor 1998), they would have problems in the progress of their study of physical science. Hence, the aim of the study was to determine primary school pupils' conceptions of energy which is to be studied in the integrated primary science syllabus, i.e., Basic 4 to 6.

3.0 **Methodology**

The short-term objective of this study was to reduce the misconceptions of pupils through well-thought out teaching and learning strategies. The long-term objective was the complete elimination or minimisation of misconceptions and the development of pupils' high order cognitive skills (HOCS) in the content of basic science. In order to achieve the objectives, a special test comprising items on concepts of heat were designed and used to test the pupils. Then after studying the outcome of the test, a post-test made up of HOCS- oriented algorithmic and conceptual-type test were administered to the pupils. The algorithmic-type items demanded mostly consequential results to a sequence. On the other hand the conceptual oriented test items required critical thinking and understanding of scientific principles.

A checklist for the attributes of "misconceptions-MC", "misunderstanding-MU", "no concepts – NC" and "correct concepts-C" were developed and used to find out the number of pupils at each of the various attributes in the post-test. This was done in order to obtain a feedback which would facilitate remedial teaching. It is well-known that meaningful interaction of pupils with their teachers through question-asking, problem-solving and critical thinking can be achieved through making connections between ideas, recalling basic theories of science and evaluative thinking of pupils (Zoller 1996). Thus the outcome of the post-test was used to test a teaching-remediation strategy in order to redeem pupils and to raise their knowledge for them to attain the required scientifically correct conceptual understanding.

4.0 **Results and Discussions**

Some of the test-items administered and the responses given are shown below. They are classified into "conceptual" and "algorithmic" types while the responses to each item are further classified as "MC", "MU", "NC" and "C".

4.1 Conceptual type test items

Q1. Explain briefly what you understand by the word energy

A1 MC – one of the answers obtained was – "energy is the power in your body when you eat good food"
MU-"energy is the light we get"
NC-"energy is a form of heat"

Q2 A diagram of a charcoal–flat press iron box was presented and pupils were asked to explain why the handle is made of wood.

A2 MC- "wood does not conduct heat away".
MU- "……wood is a bad conductor and iron is a good conductor"
NC- "……iron box is the same as the electric press iron so it has a handle of wood"

Q3 A diagram of a beaker of water and a pellet of potassium permanganate ($KMnO_4$) in it and being heated was presented. Pupils were asked to explain why a coloured column would be seen rising.

A3 MC-"the dissolved pellet is lighter than water so it rises"

MU-"…because the pellet is dissolving"
NC"…because heat energy is being supplied"

4.2 Algorithmic type test items

Q1 List any source of energy you know.
A1 MC-"..electric fan"
MU-" heat energy"
NC- "television"

Q2 Pupils were asked to state how heat energy is transferred from the bottom part of water in a container to the top part of the water
A2 MC-"…when the bottom part of the water gets hot it attracts the top liquid"
MU-"…the fire heats the bottom of the container so heat is transferred from the bottom into the liquid"
NC"…the fire under the container heats the container until the liquid becomes hot."

Q3 State the use of the holes on a charcoal-flat press iron box
A3 MC-"… to let the ashes come out"
MU-"…to let the steam come out"
NC-"…to allow light to pass through it."

In the first question under the conceptual-type, the conceptualization of the human body as merely having the power or some amount of energy as depicted in the first response is a *misconception* of the scientific fact 'energy is used in doing work'. The answer assumes the obvious fact that the human body has some amount of energy. However the generalisation required for the definition of energy, is not embodied in the answer.

In the second answer the core concept of energy as existing in different forms might have been understood. Yet the scientific fact that light is a form of energy, might not have been understood as the respondents created the impression that *light* is the energy. This is obviously scientifically incorrect.

The third response shows **no-concept** as there appears to be confusion as to what the basic definition of energy is. So *a part of a whole* (heat) has been used to replace *a whole* (energy). This shows that respondents whose thoughts are oriented in this way have no concepts about the divisions that exist in the concept of energy.

The second question also had *three* main categories of responses. The first response appears to contain the idea that *wood* is not a good conductor of heat. This is a scientific fact. Retention of heat in the box iron does not constitute a reason for the presence of a wooden handle. Thus the response constitutes a *misconception*.
In the second response, the obvious fact that iron is a better conductor of heat than wood is well known. Respondents had misunderstanding of the concept being tested. The correct answer should indicate rate of heat transfer which is known to be faster in iron than in wood.

The third answer was a complete **no-concept** response since it rather compared two different types of press irons. There was no idea of poor conductors and good conductors. The two types of press irons are used for the same purpose but the concept being tested-(conductivity) – was copiously absent in the answer.

The third question under the conceptual type depicts the concept of *convection currents* in a moving mass of fluid. The first response portrays the ideas of density. That is, a lighter body rises while a heavier one sinks. It is a misconception because without heat energy the type of rise experienced would not appear.

Answer two is the obvious dissolution process in which most solutes in liquids would have their ions or molecules moving over short distances. But this misses the important point of heat causing convection currents. It is, therefore, a misunderstanding of the concept.

The third answer does not recognize the concept "warm water rises while cold water falls". It is a fact that heat energy produces motion as pointed out in the answer but it could not conceptualise heat producing convection currents. This answer is therefore a **no-concept** one.

The algorithmic type of questions tested pure recall of acquired knowledge. They did not demand critical thinking as the conceptual types. Neither did they demand the application of knowledge to new situations.

The first answer to the first algorithmic questions cited a device that does not produce energy on its own. The fan uses electrical energy but is not a source that would produce energy on its own. This is a misconception as the realization that a source of energy produces its own energy was missed. Fans may store energy in their coils but that does not render them sources of energy.

The second answer to the first algorithmic question is a **misunderstanding** as heat energy is a form of energy but not a source. It is important for pupils to recognize that a source of energy produces type(s) of energy.

The third category of response to the first question did not consider a source as a reservoir from which devices draw their energy. It is **no-concept** to write "television" as a source of energy because it uses energy for its operation. A source is a store and this is what the answer here misses.

The second algorithmic question demanded just a recall of the modes of transfer of energy from one place to another. The first answer is a misconception, portrayed the concept of attraction. Though molecules in water have attraction for each other, it is not the concept being tested. Convection currents are the cause for heat transfer from one place to another in a liquid.

The second response indicates that some pupils misunderstood the process being asked for. Heat is not a mere substance that is being transferred into the liquid. Energy is not a substance that is moved from place to place. Instead, the process involves a gradual supply of energy to molecules whose energy increases so that they can move from one place to another. This then creates convection currents in the liquids.

The third answer does not connote any concept in heat transfer. It is a fact that the container becomes hot but the pupils have not been able to conceptualize the connection with modes of heat transfer.

The third algorithmic question asked for the use of the hole in the press iron box. The first answer that simply states that ashes will be let out is true but not scientific – it is a **misconception**. Ashes may not be of great value in the iron box as far as supply of heat energy is concerned. Thus it is the burning charcoal that becomes centre stage in the process since if the charcoal stops burning the source of energy supply will be cut off.

The second answer that steam would be let out is a misunderstanding of the scientific process required. For certain, water vapour in the box will rise and pass through the upper holes but the holes shown in the diagram were the lower holes whose function is to allow in fresh air to rekindle the burning charcoal.

To impute light in a phenomenon involving the use of the press iron box is to say the least a "no-concept". This response does not reflect the function of a press iron as a supplier of heat energy for straightening clothes.
The written responses to each question were sorted and assigned pre-determined categories of descriptions of conceptions such as Misconception- "MC", Misunderstanding – "MU", No-Concept - "NC" and Correct Concept – "C" as shown in Table 1. These categories of conceptions were devised by Zoller (1996) and used to test the mole concept for fresh undergraduate Chemistry students.

Table 1 reveals that just 51 (27.4%) of the respondents could be classified as having the correct conceptions (conceptually) and 98 (52.7%) algorithmically. The higher number at the algorithmic correct concept is an indication that many pupils learn science by rote memorization rather than by understanding correct concepts- (the deep approach -Biggs 1979; Marton & Saljo 1976; Prosser & Miller 1989). In order to test whether there existed statistically significant difference between pupils who are algorithmically inclined and those conceptually inclined a chi-square test was carried out on the responses given by pupils. The responses were on a four-point scale rating of – Correct concept (C) - 4; Misconception (MC) -3; Misunderstanding (MU)- 2 and No concept (NC) – 1. A computer-based statistical package (SPSS) was used to calculate the chi-square for the coded results. The Chi-square was used because the weighted measures were counts of pupils' performances and thus non-parametric. The outcomes of the Chi-square tests are shown in Table 2. Several combinations of Questions were correlated. For example Question 1 Conceptual versus Question 1 Algorithmic was compared to find the Chi-square value. In comparing Chi-square values for performance within categories of concepts, it was seen that there was no significant difference between conceptual questions. This means that questions within the conceptual category were equal in level of difficulty. Similarly, in-between algorithmic questions comparison yielded chi-square values that showed that there was no significant differences between questions except for Question 1 algorithmic and Question 2 algorithmic which somehow showed significant difference at the $p = 0.10$ confidence level. The interpretation here is that the two questions were not of the same level of difficulty. This may be expected particularly when pupils were only hurriedly rushed through the remedial process.

5.0 **Conclusion**

The main purpose of this study was to determine the subjects' conceptions of "energy". The data showed that there was a significant difference between those who exhibited correct concepts in the conceptual-type and algorithmic-type questions. While a larger number of pupils were algorithmically inclined they generally showed low correct concepts in all cases in both categories of concepts. This suggests that the subjects used the rote learning methods mostly. This findings is consistent with those reported in other research works (Crawford, Gordon, Nicholas & Posser 1994; Mji 1998;) that students use rote learning or memorization most of the time. Thus they tend to develop rote memory skills rather than conceptual skills (Mji, 1998). Also their performance indicated that a lot of pupils found the algorithmic type of questions easier than the conceptual type.

The study has come out with the following findings:

a) Quite a number of pupils relied too much on rote learning.
b) Only a small number of pupils (27.4%) had developed the conceptual approach to learning.

It is however, appreciated that uncontrolled factors such as pupils' background, learning environment and type of teachers might have affected the outcome of this study. It is suggested, as measures to correct the anomaly, that science should be **learned**, **understood** and **applied** to daily life situations rather than by approaching science learning through rote memorisation. Teachers should, therefore, provide activities that will enable pupils to understand concepts that are taught. Also teachers should relate concepts that they teach to real life situations. Learners come into the science classroom fully armed with their own ideas which may or may not coincide with the acceptable scientific viewpoint. What all this suggests is that despite the attempts to promote conceptual change, a satisfactory instructional model is not yet in sight. As Ogunniyi (2000) has argued, the emphasis should not be that of abandonment of what the learner has always believed but that of accommodation of the scientific worldview into his/her overall worldview such that she knows what or not was applicable in a given context.

On the other hand, the Ministry of Education (MOE) must intervene to control the proliferation of science textbooks on the market. Perhaps a sub-sector of the MOE will have to provide expert advice to the book publishing industry so as to stem the upsurge of sub-standard science textbooks. The Ghana Association of Science Teachers (GAST) has put a limited number of science textbooks on the markets but that is not enough. The association should embrace budding and enthusiastic publishers who genuinely need advice but are not financial enough to pay consultancies. Such publishers will then be offered free consultancies or highly subsidized consultancies. Alternatively, the Ghana Education service should invite would-be publishers for training and then use part of the Ghana Education Trust Fund to finance them to publish standard science textbooks for the Basic Schools.

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Notes:

Note 1.

Table 1. Frequency of pupils' responses to test items (**N=186**)

	Question Types					
Attributes	**Conceptual**			**Algorithmic**		
	Q1	Q2	Q3	Q1	Q2	Q3
MC	37	72	33	106	32	50
MU	71	59	100	37	50	39
NC	51	47	37	16	67	63
C	27	8	16	27	37	34
TOTAL	**186**	**186**	**186**	**186**	**186**	**186**

Table 1 summarises the written responses to each test item and assigned pre-determined categories of descriptions of conceptions such as Misconception- “MC”, Misunderstanding – “MU”, No-Concept - “NC” and Correct Concept – “C”.

Note 2.

Table 2. Crosstabs for Chi-Square Tests of the Responses of Pupils (N=186)

	N	Df	Chi-Square	Asymp. Signif. (2-sided)
Question 1 Conceptual Question 1 Algorithmic	186	9	21.517*	0.011
Question 2 Conceptual Question 2 Algorithmic	186	9	26.332*	0.002
Question 3 Conceptual Question 3 Algorithmic	186	9	15.180*	0.086

* Chi-Square values at p=0.10 level of confidence

Table 2 is the calculated chi-square values for the coded results. These values were used to compare Chi-square values for pupils’ performances within categories of concepts to see if there was significant difference between conceptual and algorithmic questions.