TOWARDS EFFECTING CONCEPTUAL SHIFT: AN ANALYSIS OF STUDENTS' CONCEPTUAL FRAMEWORK ABOUT PHOTOSYNTHESIS AND RESPIRATION

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Abstract

The study explored, documented the frequencies and categorized under different conceptual classes, the various conceptual difficulties confronting SSI students, seeking to understand certain biological concepts. Using diagrams, open-ended questions and structured misconception tests with conceptual change as a theoretical lens, viewpoints were elicited from 340 students. Most students gave definitions of respiration; photosynthesis and other related concepts, which were incongruent with scientifically, accepted ideas. The findings suggest that SSI student's harbour a wide range of alternative conceptions that constrain their understanding of these concepts. The study further revealed that approximately 80% of the identified difficulties fall within the conceptual change domains of class differentiation and class extension while 20% demands complete reconceptualization.

Introduction

Several researches carried out in relation to problem-solving abilities, end up with the criticism that students lack problem solving proficiency (Shaibu, 1989; Adeniji, 1985). This lack of problem ..solving skill probably might not be unconnected with the conceptual knowledge and procedural knowledge necessary to execute problem solving.

According to Gagne (1962) the acquisition of concepts is what makes learning. Thus, the importance of concepts cannot be overemphasized. A critical look at the definition of learning from a cognitive perspective further elucidates this point. Where, Langley and Simon (1981) defined learning as any process that modifies a system so as to improve, more or less irreversibly its subsequent performance of the same task or tasks drawn from the same population. Implicit in this definition is the focus on acquisition of knowledge structures rather than behaviour *per se* for it is knowledge that one learns while behaviour results from learning, rather than that which itself is learned. These knowledge structures are usually conceptualised as networks of information specifying the relationship among various facts and actions (Anderson, 1990). The knowledge structure so developed plays a critical role in learning.

Learning therefore, is characterised by a series of cognitive restructuring in which a learner's conceptual framework undergoes structural modifications based upon new experiences, information or concepts encountered (Demastes, Settlage, and Good, 1995). When pre-existing knowledge in the conceptual frame is wrong, or incorrect, learning new concepts becomes a problem.

According to Ausubel's (1968) subsumption model of learning, prior knowledge is used for interpreting the new information to be learned. He therefore, proposed the idea that meaningful learning takes place only when a general subsuming concept is already available in the learner's cognitive structure and that such idiosyncratic concepts are usually derived from the currently held concepts in the society. His point is further emphasised by Piaget (1977) who adopted a genetic epistemology, which emphasised that individuals construct their own knowledge as a result of their interaction with specific phenomena. Conceptions formed during the process constitute a person's personal explanatory knowledge of the phenomena in question. It is such concepts that usually form the basis upon which ne\v knowledge is anchored. Learners therefore make meaning by bringing their present conceptions to bear on new situations.

However, sex era! studies have shown that learners personally constructed knowledge may be quite different from currently accepted scientific views. (Driver and Erickson.1983; Osborne and \Viltrock 1983; Stewart and Kirl. 1990; Ganiell. Gnrncll and Treagust, 1990; and Bloom, 1990). Such studies have revealed I hat children's understanding is often in<idct|iia(c or erroneous (Garnelt, Garnett and Treagust 1990). The problem now remains ho\\ to shift these erroneous beliefs to scientifically valid ones.

For advocates of conceptual change, learning will be meaningful and fruitful if there is a successful shift from naive conceptions to validated ones. A key point therefore to effective lesson plan to effect shift in conceptions, will be to first identify misconceptions, and then determine the category of the change to be effected. Dykstra (1991) made this point when he said "if we find that all conceptual change can be understood as being members of categories... and that those categories are associated with general strategies which can be initialed for each member of the category, then we could have a powerful tool for inducing conceptual change". Based on experience he suggested that conceptual change should be classified info Differentiation, Class Extension and Reconceptualization. Carey (1985) in a similar vein talked of weak and strong restructuring. In weak restructuring, concepts are extended, restricted or rearranged. Restructuring in the strong sense means changes in the concepts themselves. Hewson and Hewson (1991) called Carey's strong restructuring conceptual exchange. It follows logically therefore that to teach effectively for shift of conceptions, invariably calls for categorisation of identified misconceptions, as different categories are associated with different strategies.

Purpose of the Study

The aim of (his work was to identify (he various misconceptions SSI students hold about the concepts of photosynthesis and respiration and (o classify same according to the conceptual change domain required. Hopefully to guide the teaching strategies meant to remedy the various categories of misconceptions.

Research Questions: The following questions were formulated to direct the study:

1. What fundamental misconceptions do SSI students hold about the concepts of photosynthesis and respiration'.'
2. What percentage of the identified misconceptions demand extension, differentiation and conceptual exchange or reconceptualisation?

Method

Selection Of Teaching Concepts

The choice of the concepts of photosynthesis and respiration were motivated by a number of reasons among \\hich are:

a. . Matter cycles endlessly Ihiough the U\o processes.

b. They constitute areas of high-perceived difficulty in biology and are often poorly understood and misconceived by students.

c. They are judged to be critical in the understanding of several organising conceptual schemes of the svstem including energy flow in natural systems and metabolic activities (Stoffiett, 1 994)

d. An understanding of these concepts is a pre-requisite for any systematic understanding of ecology, as food chains and food webs begin with photosynthesis and end with respiration.

Population of the Study

The study population included all year one students offering Biology in Senior Secondary Schools in Benue State of Nigeria.

Sample and Sampling Procedure

Data were collected from 355 students selected randomly from eleven schools in the state. By use of stratified random sampling, two (2) Boys' Secondary Schools, two (2) Girls' Secondary Schools and seven (7) co-educational secondary schools were selected for use from the list of accredited schools.

Development of Instrument

The research instrument consisted of diagrams, and open-ended questions. Some test items were developed based on the pattern prescribed by Anderson, Sheldon and Dubay (1990) as shown below, while some of the items were adopted from those used by other researchers.

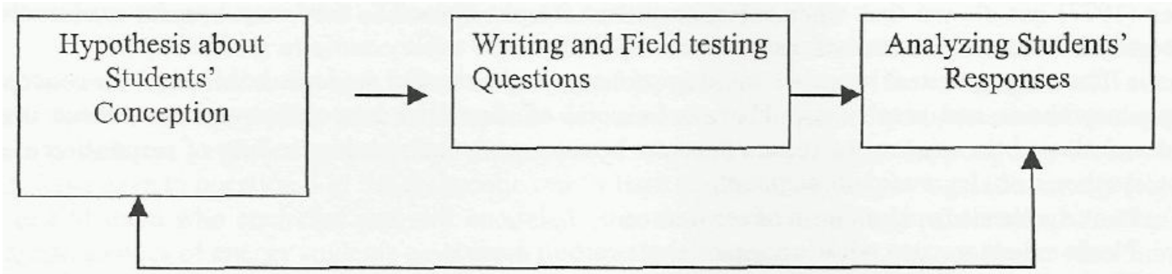

Figure 1: Cycle For Developing Misconception Test Items

Generally the test items were meant to determine students[1] understanding of the definition of food, respiration, and photosynthesis, sources of energy for plants and animals, relationship between photosynthesis and respiration as well as respiration in plants.

Content validity was estimated by asking some secondary school biology teachers, three biologists from A.B.U. Zaria, and four science educators (one in B.S.U. Makurdi and three in A.B.U.) to rate the test items with respect to accuracy, clarity, level of phrasing and the representativeness of the items from the total pool of possible relevant content.

Final test items, which numbered twelve, were selected based on Noll's (1979) suggestions, where items selected must have been judged to be appropriate by 80-100 percent **validity and** pilot tested. A set of scientifically acceptable proposition judged to be critical to a complete response of each task was provided and evaluated too.

Data Collection and Procedure For Data Analysis

The test items were administered personally to 355 SSI students. Out of 355 only 340 had complete answers. The incomplete answer sheets (n—15) were discarded.

The purpose of the test was to explore, identify and categorize students' misconceptions about photosynthesis and respiration in plants. Consequently test results were not scored, rather the frequency of occurrence of misconceptions were noted, after comparing student's responses alongside scientifically validated idea. Furthermore, the misconceptions were classified according to class bounds within conceptual change domain. These include: Class differentiation (D) Class extension (E) and reconceptualization (R).

Results and Discussion

Table 1 gives details of the various misconceptions confronting SSI students as well as the categorisation of the identified misconceptions according to the conceptual change domain under which they fall. The results revealed that students harbour a wide range of misconceptions about the study concepts.

Effective teaching in the conceptual change domain relies on the teacher having some understanding of student's viewpoints. However in the teaching of science, it would appear that few teachers might pay attention to, and make use of the personal experiences and spontaneous reasoning of students (Pope and Gilbert, 1993). For students to understand any concepts they must construct their own meaning through cognitive assimilation of the phenomenon into their existing notions, or by accommodating the existing notions to make more powerful assimilation framework, (Driver and Easily, 1978; Nussbaum and Novick, 1983) some of which are not congruent with scientific ideas. According to Nussbaum and Novick (1983) these preconceptions, misconceptions inclusive, have a crucial role in determining the longevity and qualitative content of what is learned and remembered. Pines (1977) has shown that when misconceptions are not uprooted, they may become even more elaborate and stable as a result of instruction.

The diagnostic test revealed an array of misconceptions that students hold about the concept of photosynthesis and respiration. The most crucial of identified misconceptions were those that bordered around the nucleus of these concepts. In expressing their understanding of respiration and photosynthesis, students said amongst others that:

Photosynthesis is plants form of respiration

Plants exhale oxygen while animals exhale carbon dioxide

Plants do not respire
Plants get or absorb food from photosynthesis
Plants get energy from the soil

These misconceptions give the concepts each a different identity altogether. Those results are in line with those of Wandersee (1983) and those of Songer and Mintzes (1994). These misconceptions fall within the bounds of conceptual reconoceptualization and they demand for installation of a totally new cognition.

Another alternative idea that pervaded the students' understanding of photosynthesis was their lack of understanding of the role of sunlight in the process of photosynthesis. Most of them showed faint ideas about the major function of sunlight as energy source in the process of photosynthesis. Also, many of them confused the role of chlorophyll in absorbing sunlight energy and converting same to chemical energy. Instead chlorophyll was seen as a by-product of the process or attraction of sunlight. Many students mentioned that plants make food through the process of photosynthesis, but at the same time described photosynthesis as plants' form of respiration. As a consequence most of them harboured the idea that plants don't need oxygen rather they need only carbon dioxide. Not even a single student made mention of the idea that carbon dioxide from the plant can be recycled. The common notion was that carbon dioxide used for photosynthesis must come from the atmosphere.

The role of sunlight and chlorophyll as essential factors in whose presence the raw materials of carbon dioxide and water will be converted to carbohydrate was seldom mentioned by students. Rather they did mention water, carbon dioxide, sunlight energy and chlorophyll as raw materials for photosynthesis. This finding lends credence to the finding of Ryman (1974) who found that many children considered sunlight as a reagent in photosynthesis along with carbon dioxide and water. Also it was not uncommon to find students who defined food using common, everyday language. Attempts at defining food were rarely correct but showed fragments of acceptable biological definitions. The correct biological definitions (chemical and functionally) were seldom mentioned. Most students defined food as substances that plants like animals take in from their environment.

It has been confirmed that the school science definition of food, as organic compound, which organisms can use as a source of energy for metabolic process is not consistently used even by science teachers, (Eisen and Stary, 1988). Students tended to define the conception depending on the context in which it is being used, but none mentioned that food material serves as a substrate for respiration. The misconceptualisation of the concepts of respiration and food could probably have arisen from the mixing of attributes of these concepts and/or everyday life usage of the concepts. Anderson, Sheldon and Dubay (1990) suggested that the prevailing misconceptions about respiration and food could be as a result of the fact that students' definition conformed to normal English usage, which is not acceptable for scientific usage. Bell (1985), reviewed the work of many scholars and concluded that a universal and very persistent intuitive conception in all groups is that plants get their food from their environment while roots are organs of feeding. Some students on the other hand appear to believe that plants have numerous sources of food (Roth and Anderson, 1985).

The prevailing misconceptions about these photosynthesis and respiration identified in this study could be linked to the lack of understanding of supporting concepts like energy, forms of energy and sources of energy. This probably explains why students recognised the importance of sunlight in photosynthesis, yet failed to grasp its role as energy source. This is further supported by the answers students gave to question 5 in the diagnostic test "where do you think the plant gets its energy from?" Most of them who encircled sun still encircled other distractors. Similarly when asked to mention human sources of energy students gave more than just food types but went on to mention other things. This finding is supported by those of Barker, 1985; 1986; Roth and Anderson, (1985).

One other reason for the existence of these misconceptions could be attributed to rote learning arising from the traditional method of teaching - a method that doesn't take cognisance of students' pre-instructional knowledge, and also presents knowledge as compartmentalised facts. It is not so surprising that science teaching has not been effective as we might have thought and of course has little or nothing to do with remedying misconceptions. No wonder Tasker (1981) concluded after his research that students tended to consider each lesson as an isolated event, while the teacher assumed that the students appreciated the connecting link between lessons and the previous learning experience among others. Secondly, students' knowledge structure against which learning materials were considered, were frequently not the same as the teacher assumed.

However, the classification of the misconception shows that most of the preconceptions students bring to school science classroom, require simple extension of their applications or some form of rearrangement of relationships between existing concepts.

Table 1 Classification of Some Identified Misconceptions by the Students

Ideas being tested	Categories of Conceptual change domain		
	Class extension (E)	Differentiation (D)	Reconceptualization (R)
Definition of photosynthesis	- Green plants turn sun and CO_2 from air into chlorophyll. - Plants take in CO_2 from air and exchange it with oxygen Inappropriate relationship between sunlight, food and photosynthesis (60%)	Other functions of sunlight - Other functions of chlorophyll 20%	- Plants get, absorb food, not make food. - Photosynthesis is plants form of respiration 20%
Definition of rcspiiation	- Oxygen replaces $C0_2$ in cells - Respiration is related to photosynthesis in terms of food but not energy - Process by which iiving things take in oxygen (33.3%)	- Breathing - Air in, air out - Confused respiration with digestion - Confused respiration with gaseous exchange 53.3%	- Exhaling CO_2 for human exhaling O_2 for plants - Plants don't respire 13.3%
Sources of energy for plants and human beings	- Inappropriate relations between Respiration, Energy and Food. Mainly misconceived forms of energy 22.2%	- Gets energy by process of photosynthesis 66.7%	- Plants get energy from the soil with help of the root. 11.1%
Definition and sources of food for plants and animals	- Incorrect and incoherent definitions - Food for plants as absorbed from the soil (62.5%)	Confused idea of different classes of food (25%)	- Food for plant defined as nutrition, which bums in air to produce energy (12.5%)
Relationship between photosynthesis and cellular respiration	- Difficulty in explaining other sources of $C O_2$ Inability to explain energy conversion during photosynthesis and respiration (21.4%)	- Plants undergo cellular respiration but different from us. 21.4%	- Alternate role of oxygen Alternative sources of energy - Plants don't respire 57.2%
Application of knowledge of photosynthesis and respiration	- Mere description of bacteria distribution - Incoherent response (30%)	-Misconceived experiment to be light and dark phases of photosynthesis - Alternative function of chlorophyll. - Alternative role of light in experiment. 70%	

Conclusion and Educational Implications

Based on the findings of the work, the following conclusions were drawn:

1. Students entering SSI biology class possess a variety of misconceptions about photosynthesis and respiration.
2. Approximately 80% of these misconceptions fall within the conceptual domains of differentiation and extension, while 20% fall within the class bounds of reconceptualisation.

Misconceptions falling within differentiation and class extension demand real restructuring. Restructuring in these instances demand that applications of concepts are extended restricted or rearranged. In differentiation, new concepts emerge from existing more general concepts, while in extension, existing conceptions are found to be cases of one broader notion. Reconceptualisation on the other hand involves changes in the concepts themselves. Here there is a significant change in the nature of and relationship between conceptions.

For conceptual change studies, the important aspect of the student learning is the alternative conceptions brought into science instructions. Students use their prior knowledge to attempt to make sense of the instructions that their teachers provide. For students to achieve the aims of science education, they must acquire full scientifically validated conceptions. Implicit in this is that, misconceptions, which exist within the students' conceptual framework, must be shifted to scientifically valid ideas. Biology educators in particular and science education researchers as a whole therefore, need to focus their attention on these alternative frameworks with a view to bringing out the misconceptions alongside with the scientifically validated ideas so that people become aware of the possible problem areas. Furthermore, if identified misconceptions are properly classified, formulation of well thought out conceptual change instructional lessons would become easier.

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