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Author(s)	Lee Yew Jin and Diong Cheong Hoong
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Misconceptions on the Biological Concept of Food: Results of a Survey of High School Students

Lee Yew Jin
Victoria School, Singapore
&
Diong Cheong Hoong
School of Science
NIE/Nanyang Technological University

Abstract

A questionnaire survey was administered to 66 secondary 5 Normal level students in Singapore to sample students' ideas on the scientific concept of food in school biology. Between 30% to 60% of the respondents believed that food yielded energy but this concept was context dependent and not widespread. Primary responses predominated as students felt that the biological functions of food were for sustenance, satiation, growth and general well-being. They seemed to hold a simplistic view that anything that was consumable (edible) was considered to be a food. More than 75% of the sample accepted the idea that food can be in liquid state. Students' understanding of the biological concept of food was anthropocentric and not applied across living organisms in heterotrophs (animals) or autotrophs (plants) as a whole. The components of a balanced diet were understood but many students confused the concepts of nutrients and water, believing the latter to be a food.

Introduction

Psychologists have long believed that learning is a highly complex process involving an individual interacting with external environmental and internal cognitive factors. Presently, cognitive learning theorists seem to be able to account for more of the learning processes than behaviourists. Their (cognitivists) ideas will thus form the framework in the investigation of some Singapore high school students' understanding on the scientific concept of food in the biology curriculum.

Failure to learn might involve among other things, lack of; cognitive preparation *a la* Novak, qualitative mental operations *a la* Piaget, relevant subsumers *a la* Ausubel and mastery of specific component skills *a la* Gagne (Simpson & Arnold, 1982a,b). More recently, the constructivist viewpoint emphasises that a learner's prior knowledge greatly affects learning because he modifies, organises and stores information not necessarily in the same way he received them. Either the learner abandons his prior experiences and learning completely (which is rare) when confronted with formal instruction or more commonly, there will be some form of syncretism (Gilbert, Osbrone & Fensham, 1982). Thus, alternative frameworks or misconceptions arise and these can act as impediments to science learning.

Other labels that are used to describe misconceptions in science, used often interchangeably, include spontaneous reasoning, children's science, alternative frameworks, naive ideas and preconceptions. Misconceptions (Driver, Guesne & Tinberghian, 1985; Gilbert, Osbrone & Fensham, 1982) share some characteristics listed below, with examples related to biology;

a. perceptually dominated thinking (e.g. light is essential for plants lest they die/fall sick)
b. limited focus (e.g. water is more important than food)
c. linear causal reasoning (e.g. food gives energy, food is digested, thus digestion gives energy)
d. undifferentiated concepts (e.g. food is anything edible)
e. context dependency (e.g. food in one situation is not food in another)
f. everyday language (e.g. respiration is breathing)
g. self-centered and anthropocentric thinking (e.g. food to human food)
h. teleological (e.g. food is food because it is edible).

The topic on food was chosen to investigate students' misconceptions because it is fundamental to understanding other related concepts in biology, for example respiration, nutrition and photosynthesis. Furthermore, all these topics have been found to be conceptual minefields for students across cultures. Yet, these topics form the foundations of biology and can be found in the spiral curriculum in the school syllabus from primary to tertiary levels.

Materials and Method

The sample comprised 66 secondary 5 Normal stream students aged 16 to 18 years from two high school classes who represented students in a less academically inclined group. Of the total sample, 29 were girls and 37 boys. The students studied combined science (Biology/Chemistry) in the two preceding years prior to participating in this questionnaire survey.

A 16-item questionnaire was developed to sample student misconceptions that research have shown to occur in the topics on food, photosynthesis and respiration. Items included multiple choice and free response questions (see Treagust, 1988). The instrument was pilot-tested among a sample of postgraduate biology students at the National Institute of Education. The questionnaire was administered to the classes separately and respondents were given 40 minutes to complete the questionnaire.

Results and Discussion

Six items in the survey questionnaire pertain to the topic of food and their analyses form the basis of this paper. Nil response as well as non-answer (nonsense replies or tautologies) were also scored. In order not to under-represent rare or unusual student replies under larger, more inclusive categories, as many representative conceptions from students' answers are recorded in the following tables. Responses were not represented in percentages because of the small sample size.

Q1. How do you define the term "food"?

Student definitions of food	**Frequency (n=66)**
gives energy only	9
gives energy, nutrients, carbohydrates	4
gives energy, strength	1
gives energy, vitamins	3
gives energy, and to live	3
gives energy, and to fill stomach	3
can be eaten, consumed	15
contains nutrients, vitamins	7
for growth, survival	17
to fill stomach, satiation	2
to make us strong	1
Non answer	1

Table 1. Student definitions on the biological concept of 'food'.

While there appears to be no agreed definition of food (Barker & Carr, 1989); it is generally accepted that food gives utilisable energy to a living organism which is used firstly for maintenance, and secondly for growth, tissue repair and reproduction (Bishop, Roth & Anderson, 1986; Bushell & Nicholson, 1985; Mayes, 1988; Mackean, 1986; Roth, 1985). The everyday conceptions of food which are used in a loose manner (see Ferrer et. al. 1990; Simpson & Arnold, 1982b) serve no purpose except to confuse the issue. The concept of food was also found to be variable and context dependent according to research done by Barker (1985, cited in Ferrer et. al., 1990).

Twenty-three respondents (34.4%) gave secondary-type of responses (see Simpson & Arnold, 1982b) when they mentioned that food either gave energy only or in addition to doing something else (see Table 1). In a British Survey, Simpson and Arnold (1982b) found that 54-62% of 14-16 year old students mentioned the provision of energy in relation to food. Eisen and Stavy (1988) reported that in Israel this figure was 40% for biology majors and 27% for non-biology majors. In our survey, primary responses for example, "food can be eaten, is consumable, contains nutrients, foods are prerequisites for survival" accounted, unfortunately, for the most of the answers (63.6%). Indeed, Simpson and Arnold (1982b) believe that this can be attributed to children being told to "eat well" or to "eat up to grow big" and thus food is often associated with growing. Roth et al. (1983, cited in Bell, 1985) opined that the circuitous explanation that food is needed in order to live does not relate the function of food to the internal metabolic processes in organisms. Nonetheless, this reasoning was found to be very common indeed in this survey.

Bishop, Roth and Anderson (1986) caution against accepting student responses such as "food is energy" since students often confuse the notion of conservation of matter/energy in respiration and photosynthesis. As such, the authors suggested that students should be taught the food concept in functional terms as organic matter which provides energy for tissue metabolism and allocation of stored energy for growth.

Q2. Why is eating an important animal activity?

There were two main groups of responses. Firstly, 64% (n=66) of respondents held the conceptual framework that the purpose of "eating food" was to "obtain energy". Surprisingly, the energy-giving nature of food showed much lower values of 34.8% and 27.2% in Q1 and Q6 respectively. There seemed to be a conception that eating food gives energy but energy is not equivalent to food *per se*. Data from Simpson and Arnold (1982a) revealed that half of 12-13 and a third of 14-16 year olds from their sample thought that energy comes from food, food is then digested and thus digestion not respiration releases energy!

Secondly, 32% (n=66) of respondents gave conceptions on food consumption which did not go beyond surface-level processing. Their preconceptions of food centered on satiation ("to fill stomach"), general well-being ("for health and nourishment") and for life and living ("to live and grow"). They have thus completely missed the critical point of eating food. A possible factor might have been the cliched saying "eat to live, not live to eat".

Q3. A man was injured in a car accident and taken to hospital in an unconscious condition. Since he cannot eat, he was put on an intravenous drip of glucose and saline (that is a needle is inserted into a vein through which the solutions were introduced). Is the man taking in food? Explain your answer as fully as possible.

The majority, 79% of respondents correctly believed that the man was indeed taking in food (see Table 2). Intriguing were the 11 students who believed that the intravenous drip was a substitute or some kind of food. It would have been insightful to probe these students' minds further to investigate whether they thought liquid glucose is still a food by biological digestion, even if it is not passed through the gut or blood system by intravenous drip.

	Frequency		Frequency
Not food	**4**	**Is food**	**52**
take medicine	1	no answer	4
glucose provide energy	2	non answer	1
only for functioning	1	IV is food	19
		gives energy	16
		chemical reaction for heart to beat regularly	1
		some kind or substitute for food	11

no answer=10

Table 2. Student responses for Q3 on whether an intravenous drip was considered to be food.

Q4. What happens if a person eats only carbohydrates (in the form of polished rice) for one month?

	Frequency
unbalanced diet, falls ill, deficiency disease	38
grows thin	6
grows fat	8
no growth	1
dies	1
no answer	11
non answer	1

Table 3. Student responses for Q4 on the concept of a balanced diet.

This is a content knowledge question and it was relatively well answered with 38 students (57.5%) describing it as an unbalanced diet or in terms of its symptoms - deficiency diseases (Table 3). The other responses were interesting as some thought that the man would lose weight while others were convinced the opposite would occur!

Q5. Living things cannot survive without water. Would you group water under the term "food"?
YES, water is a food because (explain as fully as possible)
NO, water is not a food because (explain as fully as possible)

	Frequency		Frequency
Not food	**11**	**Is food**	**40**
non answer	1	non answer	1
liquid not food	2	to live, survive,	
essential for metabolism,		more vital than food	28
survival	4	for respiration	1
no energy	4	quench thirst	1
		body has lots of water	4
		contains energy	5
no answer	4		
non answer	11		

Table 4. Student responses for Q5 on whether water was a food.

It is no surprise in Table 5 that so many students (40 or 60% of sample), held onto the misconception that water is food as some standard textbooks (Exploring Science I, 1982; Lam, 1989; Soper & Smith, 1976) explicitly define it as such while Jones and Jones (1987) do so by implication. Water does indeed serve myriad functions as many students answered yet it does not satisfy the basic criteria of energy supply that makes it a food (Bishop, Roth & Anderson 1986; Bushell & Nicholson, 1985; Mackean, 1986; Roth, 1985). The students gave primary responses and only 4 judged water not to be a food since it provided no energy.

Q6. Study the list of items given below and answer the questions as directed: Tick (/) if you think it is a food, cross (x) if you think it is not a food. Why are the items you have ticked called food? Why are the items you have crossed out not called food? Give your reasons.

	Frequency		
IT IS A FOOD	**YES**	**NO**	
petroleum	0	66	
cotton wool	2	64	
paper	7	59	
soil	8	58	
wood	13	53	
fertiliser	22	44	
chewing gum	25	41	
insects	34	32	
seeds	38	26	no answer=2
grass	45	21	
vitamins	55	11	
fruit juice	58	8	
milk	61	5	
vegetables	65	1	
fruits	65	1	
meat	65	1	
rice	66	0	

	Frequency	
It is food because		
it gives energy	18	**but others are not food because**
no energy	12	
source of energy	1	
inedible	4	
no vitamins	1	
is edible	29	**but others are not food because**
no answer	1	
non answer	1	
inedible	24	
common sense	1	
unnecessary for life	2	
can fill stomach	1	**but others are not food because**
inedible, not fill stomach	1	
has organic nutrients	12	**but others are not food because**
no answer	3	
non answer	4	
inedible	4	
not stop hunger	1	

needed to survive	1	**but others are not food because**
poison, for other uses	1	
no answer	4	
non answer	1	

Table 5. Student responses for Q6 arranged from the least to the most "food-like".

This question yields some interesting insights after arranging the items from the least to the most 'food-like' in Table 5. Petrol was not considered a food at all though it is known that certain microbes do consume it. Neither were cellulose materials e.g. cotton wool, paper, and wood popular choices (3%, 10.6% and 19.7% respectively) in spite of the existence of termites and ruminants being able to consume it. A possible reason for these results could be plain ignorance. It is debatable whether chewing gum is a food since it contains sugar but apparently less than 40% of our students believed it to be so. This is believed to be due to students considering an animalistic conception of food; food being something for man or animals. As can be seen, nearly half believed food was food because it was edible, very teleological indeed!

Each of the items from vitamins to rice was considered to be food by at least 75% of the sample with the last four considered extremely 'food-like'. Vitamins, while not considered a food by scientific definition accounted for 83.3% of responses. According to Ferrer et al (1990), much ambiguity also exists in defining everyday conceptions of food which includes drinks, snacks and confectionery. Juice and milk in their cross-cultural report on young children in Australia and Malaysia were not popular choices as food, contrary to our survey. Rice, as these authors have found, was considered very food-like by Malaysian children as it supplied lots of energy. Similarly, rice scored 100% affirmations in this sample.

Summary

This brief survey had highlighted insights into some Singapore high school students' ideas about the topic of food while being mindful of the small sample size involved. Though 30% to 60% of the students said that food yielded energy, this concept was context dependent and not very widespread. Food was just like fuel since both yielded energy but few appreciated the idea of useful chemical energy which can be utilised by one system and not the other. Primary responses predominated as students felt that food was for living, filling the stomach, essential for health and growth or that which can be eaten. Indeed, students could identify what was food and more than three quarters could accept the idea of food in liquid form. Students' understanding of the biological concept of food was anthropocentric and not applied across living organisms in heterotrophs (animals) or autotrophs (plants) as a whole. The components of a balanced diet were understood but many students confused a nutrient, water, to be a food. In other words, they thought food was equivalent to nutrients and vice versa. Water although considered to be a nutrient is not a food as it does not yield biological energy to organisms. Understanding the concept of food is basic in science. Teachers need to emphasise food is any substance, in solid or liquid state, by which any organism can obtain energy through the process of respiration.

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