The study of grade 10 students' conceptual understanding of chemical reactions and biomolecules

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Abstract
The purpose of this research was to study grade 10 students' conceptual understanding of chemical reactions and biomolecules. The target group was 33 10^{th}-grade students of classroom 14, Phadungnaree School, Thailand, in the first semester of the academic year 2016. The instruments for the conceptual understanding measurement were multiple choice test with rationale explanation and semi-structured interview. The findings on the students' conceptual understanding were analyzed and categorized using the criteria of Westbrook and Marek, which divide the conceptual understanding into five levels, namely 1) complete understanding (CU), 2) partial understanding (PU), 3) partial understanding with specific alternative conception (PS), 4) alternative conception (AC) and 5) no understanding (NU).
The results showed that most of the students' conceptual understanding of chemical reactions and biomolecules was at the AC level. The chemical reactions concept consisted of process of chemical reaction, chemical equation, type of chemical reaction, rate of reaction and factors that affect rate of reaction with AC percentages of 66.67, 51.51, 54.55, 48.48 and 57.58, respectively. The biomolecules concept consisted of structure and composition of fat and oil, properties of fat and oil, types of carbohydrates, properties of carbohydrates, structure and composition of protein, properties of proteins and types of nucleic acids with AC percentages of 66.67, 72.73, 60.61, 66.67, 69.70, 51.52 and 63.64, respectively.

Keywords: Chemistry education, concept misunderstanding

Introduction

Science has been accepted to have an extreme influence on people and societies around the world. For this reason the main aim of national educational policy of many countries, including Thailand, is to promote science conceptual understanding as well as to conduct many researches for developing science curriculum that best fits all students. It is arguable that the science curriculum still lacks connection between science concepts and daily life that is interesting for student and easy to understand. Therefore, the real life or familiar situation could promote students' learning in science (Yasushi, 2009)

Conceptual understanding is the ability to interpret, translate, explain all information about a particular topic from observation and experience and process it to create an idea about the topic. Over the past decade many researchers have been interested in students' conceptual understanding of chemical phenomena either prior to or following instruction, especially chemical reactions and biomolecules, which are basic concepts in chemistry (Peterson, Treagust, & Garnett, 1989). Life processes occur via chemical reactions of biomolecules, and thus understanding biomolecules and chemical reactions is vital. Moreover, chemical reactions are used for synthesizing, decomposing, or transforming compounds. However, the interview with chemistry teachers revealed that students' learning of chemical reactions was indeed problematic (Tan & Treagust, 1999). It seems that many students are still confused about these topics. When students have misconception about the chemical reaction or biomolecules, they will not be able to apply right concepts to describe events in life. In addition, topics in chemistry are related to each other. Prior learning concept is the basis of the concept of the next study (Waraporn Tirisiri, 1989). If students did not understand previous chemistry concepts, it would be difficult for them to understand new chemistry concepts effectively. Therefore, teachers must know how their students perceive the concepts of chemical reactions and biomolecules prior to designing appropriate learning activities to make the students understand the concepts correctly.

We attempt to survey the conceptual understanding of grade 10 students in Phadungnaree School, Mahasarakham Province, Thailand. The information will be useful and can be applied in the learning activities for improving students' conceptual understanding.

Research Purposes

The purpose of this research was to study grade 10 students' conceptual understanding of chemical reactions and biomolecules.

Participants

The participants of this study consisted of 33 10^{th}-grade students of classroom 14 in Phadungnaree School, Thailand, in the first semester of the academic year 2016.

Research Instruments

The instruments for the conceptual understanding measurement were multiple choice test with rationale explanation and semi-structured interview. The multiple choice test with rationale explanation contained five questions on chemical reactions and seven questions on biomolecules. The findings on the students' conceptual understanding were analyzed and categorized using the criteria of Westbrook and Marek (1992), which classify students' conceptual understanding into five levels as follows:

1. Complete Understanding(CU): Responses that include all components of the validated response
2. Partial Understanding (PU): responses that include at least one of the components of validated response, but not all the components
3. Partial Understanding with Specific Alternative Conception (PS): responses that show understanding of the concept, but also make a statement, which demonstrates a misunderstanding
4. Alternative Conception (AC): responses that include illogical or incorrect information
5. No Understanding (NU): responses that repeat the question or contain irrelevant information or an unclear response or leave the response blank

Procedures

This research studied the students' conceptual understanding of two topics in chemistry, namely, chemical reactions and biomolecules. The chemical reactions concept consisted of process of chemical reaction, chemical equation, type of chemical reaction, rate of reaction and factors that affect rate of reaction. The biomolecules concept consisted of structure and composition of fat and oil, properties of fat and oil, types of carbohydrates, properties of carbohydrates, structure and composition of proteins, properties of proteins and type of nucleic acids. Steps in the process of conceptual understanding measurement were as the following:

1. The researchers studied basic data about conceptual understanding.
2. The methods for conceptual understanding measurement were created by the following procedures:
   2.1. The researchers studied the literature review on levels of conceptual understanding, conceptual understanding measurement, and semi-structured interview.
   2.2. The researchers created the methods for conceptual understanding measurement comprising multiple choice questions with rationale explanation and semi-structured interview.
   2.3. The multiple choice questions were investigated by three experts to determine the congruence of the questions and the objectives.
   2.4. The researchers analyzed the congruence results, which showed an Index of Item Object Congruence (IOC) between 0.60 – 1.00.
3. The students' conceptual understanding data were collected using the multiple choice questions with rationale explanation.
4. The data were analyzed and categorized using the criteria of Westbrook and Marek (1992).

5. The researchers interviewed the students using the semi-structured interview. The data from the interviewing were analyzed using content analysis.

Results

Table 1 shows the levels of the 33 students' understanding of the five concepts of chemical reactions. The results indicated that the conceptual understanding of most students was at the AC level. The percentages of the AC level on the process of chemical reaction, chemical equation, type of chemical reaction, rate of reaction and factors that affect rate of reaction, were 66.67, 51.51, 54.55, 48.48 and 57.58, respectively.

Concept	levels of conceptual understanding (number of participants)									
	CU	%	PU	%	PS	%	AC	%	NU	%
Process of chemical reaction	0	0.00	2	6.06	7	21.21	22	66.67	2	6.06
Chemical equation	0	0.00	4	12.12	10	30.30	17	51.51	2	6.06
Type of chemical reaction	0	0.00	1	3.03	6	18.18	18	54.55	2	6.06
Rate of reaction	1	3.03	2	6.06	11	33.33	16	48.48	3	9.09
Factors that affect rate of reaction	0	0.00	1	3.03	9	27.27	19	57.58	4	12.12

Table 1: The levels of students' conceptual understanding of chemical reactions**.**

Note: CU = complete understanding, PU = partial understanding, PS = partial understanding with specific alternative conception, AC = alternative conception and NU = no understanding.

In each concept of the chemical reactions, the students showed misconception understanding as follows:

1. In the process of chemical reaction concept, the students explained that "kinetic energy must be higher than activation energy in order to make a reaction". But in fact, kinetic energy might be higher than or equal to activation energy for making reaction.

> "*For making reaction, kinetic energy must be higher than activation energy*."
>
> *(Interview student A, August 1, 2016)*
>
> "*kinetic energy must be higher than activation energy for making a reaction*."
>
> *(Interview student D, August 1, 2016)*

2. In the chemical equation concept, the students explained that "there are three types of phase of the reactants and products, consisting of solid (s), liquid (l), or gas (g)". But in fact, there are four types, consisting of aqueous (aq), solid (s), liquid (l), or gas (g).

> "*There are three types of phase of the reactants and products, namely, solid (s), liquid (l) and gas (g).*"
>
> *(Interview student B, August 1, 2016)*
>
> "*The phases in the reaction are: solid (s), liquid (l), gas (g).*"
>
> *(Interview student F, August 1, 2016)*

3. In the type of chemical reaction concept, the students explained that "the decomposition reaction is the breakdown of one substrate into two products". But in fact, the decomposition reaction is the breakdown of one substrate into two or more products.

> "*Decomposition reaction, one substrate will be broken down to two products.*"
>
> *(Interview student C, August 1, 2016)*
>
> "*One substrate will be broken down to two products, this reaction is called decomposition reaction*."
>
> *(Interview student G, August 1, 2016)*

4. In the rate of reaction concept, the students explained that "calculation of rate of reaction, is achieved by taking time, divided by amount of substance". But in fact, the calculation is achieved by taking the amount of substance, divided by time.

> "*When we calculated the rate of reaction, we took time, divided by volume or amount of substance*"
>
> *(Interview student D, August 1, 2016)*
>
> "*I calculated the rate by determining the volume of a gas at various times. I took time, divided by volume of gas*"
>
> *(Interview student H, August 1, 2016)*

5. In the factors that affect rate of reaction concept, the students explained that "surface area and temperature don't affect rate of reaction". But in fact, the factors that affect rate of reaction consist of concentration, surface area, temperature and catalyst.

> "*When temperature or surface area changed, the reaction will not change.*"
>
> *(Interview student E, August 1, 2016)*
>
> "*The temperature of a reaction doesn't affect reaction rate*."
>
> *(Interview student B, August 1, 2016)*

Table 2 shows the levels of the 33 students' understanding of the seven concepts of biomolecules. The results indicated that the conceptual understanding of most students was at the AC level. The percentages of the AC level on the structure and composition of fat and oil, properties of fat and oil, types of carbohydrates, properties of carbohydrates, structure and composition of protein, and properties of protein and type of nucleic acid were 66.67, 72.73, 60.61, 66.67, 69.70, 51.52 and 63.64, respectively.

Concept	levels of conceptual understanding (number of participants)									
	CU	%	PU	%	PS	%	AC	%	NU	%
Structure and composition of fat and oil	0	0.00	0	0.00	10	30.30	16	66.67	7	21.21
Properties of fat and oil	0	0.00	1	3.03	6	18.18	24	72.73	2	6.06
Types of carbohydrates	0	0.00	2	6.06	10	30.30	16	60.61	5	15.15
Properties of carbohydrates	0	0.00	2	6.06	7	21.21	20	66.67	4	12.12
Structure and composition of proteins	0	0.00	0	0.00	8	24.24	23	69.70	2	6.06

Properties of proteins	0	0.00	2	6.06	11	33.33	17	51.52	3	9.09
Type of nucleic acids	0	0.00	0	0.00	8	24.24	21	63.64	4	12.12

Table 2: The levels of students' conceptual understanding of biomolecules
Note: CU = complete understanding, PU = partial understanding, PS = partial understanding with specific alternative conception, AC = alternative conception and NU = no understanding

In each concept of the biomolecules, the students showed misconception understanding as follows:

1. In the structure and composition of fat and oil concept, the students explained that "structure of fat consists of three molecules of glycerol and three molecules of fatty acid". But in fact, the structure of fat consists of one molecules of glycerol and three molecules of fatty acid.

"*The structure of lipid consists of three molecules of fatty acid and three molecules of glycerol*"

(Interview student F, August 3, 2016)

"*Fats are esters of three molecules of glycerol with three molecules of fatty acid.*"

(Interview student I, August 3, 2016)

2. In the properties of fat and oil concept, the students explained that "the single bond reaction of fatty acids causes rancidity". But in fact, the double bond reaction of fatty acids causes rancidity.

"*The single bond reaction of fatty acids causes rancidity.*"

(Interview student G, August 3, 2016)

"*Single bond can affect oil to become rancid*."

(Interview student J, August 3, 2016)

3. In the types of carbohydrates concepts, the students explained that "disaccharides are produced by two molecules of monosaccharide with a peptide bond". But in fact, the bond is a glycosidic bond.

"*A peptide bond is a bond linking two monosaccharides to form a disaccharide*."

(Interview student A, August 3, 2016)

"*Disaccharide is formed when two monosaccharides are joined by a peptide bond*."

(Interview student H, August 3, 2016)

4. In the properties of carbohydrates concept, the students explained that "starch can be tested with Benedict's test". But in fact, Benedict's test is used to test for monosaccharides and disaccharides but not for sucrose and chemical test for starch is to add iodine solution.

"*Benedict's reagent is a chemical reagent commonly used to detect starch*."

(Interview student E, August 3, 2016)

"*The Benedict*'s *test is used to* test *starch*."

(Interview student K, August 3, 2016)

5. In the structure and composition of proteins concept, the students explained that "proteins are made up of small units called nucleic acids that are attached to one another by peptide bonds". But in fact, the smaller units are called amino acids.

"*Proteins are large biomolecules, consist of long chains of*

nucleic acids."

(Interview student H, August 3, 2016)

"*Proteins are made from smaller molecules called nucleic acids*"

(Interview student B, August 3, 2016)

6. In the properties of proteins, the students explained that "protein denaturation is a physical change and the properties of proteins do not change". But in fact, denaturation is the alteration of a protein shape through some form of external stress (for example, by applying heat, acid or alkali) and whose properties such as viscosity, absorption of ultraviolet light will change abruptly.

"*Denaturation is a process in which proteins lose their shape, but their properties remain the same.*"

(Interview student A, August 3, 2016)

"*Denaturation, proteins lose structure but properties remain the same.*"

(Interview student L, August 3, 2016)

7. In the type of nucleic acids concept, the students explained that "small units of DNA and RNA are called amino acids". But in fact, the small units are called nucleotides.

"*RNA is amino acids polymer*."

(Interview student D, August 3, 2016)

"*DNA, RNA are made up of chains of amino acids*."

(Interview student M, August 3, 2016)

Conclusions and Discussions

The results indicated that most of the students' conceptual understanding of chemical reactions and biomolecules was at the AC level. The AC percentages of chemical process of chemical reaction, chemical equation, type of chemical reaction, rate of reaction and factors that affect rate of reaction were 66.67, 51.51, 54.55, 48.48 and 57.58, respectively, while the AC percentages of structure and composition of fat and oil, properties of fat and oil, types of carbohydrates, properties of carbohydrates, structure and composition of proteins, properties of proteins and type of nucleic acids were 66.67, 72.73, 60.61, 66.67, 69.70, 51.52 and 63.64, respectively.

According to the study of the students' conceptual understanding related to chemical reactions and biomolecules, it was found that most students misunderstood the five following concepts: process of chemical reaction, factors that affect rate of reaction, properties of fat and oil, structure and composition of proteins and type of nucleic acids, as considered from the numbers of the students whose levels of understanding were at the AC and NU levels. When considering the multiple choice test with rationale explanation and data from the interviewing concerning the five concepts above, it was found that the questions were related to structures or processes at the molecular level in which the students had to use their imagination and build the mental models by themselves for making their understanding. If in the learning activity, the teacher could not provide the media or real model in the classroom, the students would lack a chance to learn by doing, which worsening their chance for conceptual understanding. Moreover, in the past, teachers often taught chemical reactions and biomolecules by merely explanation or having some illustrations, and as a result, the teachers could not explain the steps or process of chemical reactions at the molecular level clearly, and the students hardly imagined and then misunderstood

the concepts. In the learning process that encourages students to analyze information and to have concrete visualization by themselves, the teacher may use simulator or video that can help the students apply their experience. Consequently, the students will get more in-depth understanding than just reading textbooks and listening to teachers in the class, leading to improving the students' conceptual understanding to the CU level (Nadh Ditcharoen, 2014). This statement was supported by Viladislav (2009) which explained that using three-dimension images or video media could help learners see the empirical images, enabling the learners to have better understanding of the processes or complex structures. Tsoi (2008) studied the conceptual understanding of students who participated in the learning activities focusing on the use of video media and three-dimension images. The results of Tsoi's study showed that using video media or three-dimension images could enhance the higher learners' conceptual understanding.

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