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Using Analogy and Model to Enhance Conceptual Change in Thai Middle School Students

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This study examined conceptual change of Thai middle school students after learning photosynthesis with analogy and model. The analogy mapped key features from the analog (cooking food) to the target concept (photosynthesis). Modeling photosynthesis activity provided the opportunity for students to understand how plants use sugar to synthesize cellulose and starch. To determine students' prior knowledge, the photosynthesis questionnaire was administered to 58 Grade 7 students of urban school. The result revealed that students held alternative conceptions in many aspects, including the origin of plant nutrients, the substances required for photosynthesis, the products of photosynthesis and the role of chlorophyll. After the instruction, the students were post-tested to determine how students' conceptions had changed. The result indicated that the students demonstrated better comprehension than that of the pre-test. The percentage of students who changed their ideas to the scientific one was reported and discussed. The present study has implication for both science educators and science teachers who are interested in teaching with analogy and model.

Keywords: analogy, model, conceptual change, photosynthesis

Introduction

Photosynthesis is considered as one of the essential topics in school biology, because it is the fundamental idea for students to understand how the components in an ecosystem are related to each other (Marmaroti & Galanopoulou, 2006). Many studies on students' learning photosynthesis in the past, however, revealed the difficulties of students to understand this idea, and the students' alternative conceptions related to photosynthesis were identified. Several studies suggested that students were not able to recognize the reactants and the energy transfer occurring during photosynthesis process, and they also confused photosynthesis with plant respiration (Haslam & Treagust, 1987; Stavy, Eisen, & Yaakobi, 1987; Marmaroti & Galanopoulou,

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2006). It is not surprising that students have difficulties to understand photosynthesis, because this biological process is far from students' experiences and is very abstract. Harrison (2008) pointed out that the attraction of analogies in science lies in the ability to explain abstract ideas in familiar terms. In this study, analogy mapped key features from an analog (cooking food) to the target concept (photosynthesis), in order to explain the unfamiliar concepts by comparing them to the familiar ones. The target concepts were substances needed for photosynthesis, energy used in the process, and substances produced during photosynthesis. In this study, modeling photosynthesis was also used to explain how plants use carbon dioxide and water to synthesize sugar and convert to cellulose and starch. This activity was adapted according to Vandiver (2009). Duit (1991) viewed the model as a tool for providing analogies, because both model and analogies have common features considering the structural mapping of different domain. In order to determine how students' conceptions changed after the instruction, certain questions from the photosynthesis questionnaire developed by Marmaroti and Galanopoulou (2006) were administered before and after the instruction. The important feature of this questionnaire is that the distracters were representative of typical conceptions and alternative conceptions of students. We compared students' responses to the questions before and after the instruction and discussed how students' conception had changed over the instruction.

This study intended to examine the possibility for using analogy and model in a middle school plant biology classroom. It was a part of ongoing research project focused on developing learning units on plant biology incorporated with analogy technique. The main objective of the present study was to explore how Grade 7 students' conceptions on photosynthesis had changed after the instruction using pictorial analogy and modeling activity.

Methodology

Participants

The participants were 58 Thai Grade 7 students, aged between 12 and 13 years, attending one science class of a secondary school located at an urban area in Bangkok, Thailand.

Design and Materials

One-group pretest-posttest design was used as the research design to examine how students' conceptions on photosynthesis had changed after the instruction. The student participants received the instruction incorporating analogy and model as follow.

Pictorial analogy activity. In this activity, students received a lecture comparing photosynthesis (target concept) with cooking food (analog concept) depicted in a pictorial diagram on students' worksheet (see Figure 1 (a)). Following the teaching with analogies model (Glynn, Duit, & Thiele, 1995), the instructional sequence was that: (1) introduce the target concept (photosynthesis) to students; (2) remind students of what they know of the analog concept (cooking food); (3) identify relevant features of photosynthesis and cooking food; (4) map similarities between photosynthesis and cooking in which both processes need raw materials and energy to synthesize products; (5) indicate where the analogy break down in which the raw materials, energy and products of photosynthesis are different from ones of cooking food; and (6) draw conclusions about the photosynthesis process. The role of students was to identify the common attributes between the analog concept and the target concept and also the difference between them.

Modeling photosynthesis. This activity followed the pictorial analogy. A group of students was asked to build paper-clips model of sugar from carbon dioxide and water. Then, they attached their sugar model with the one belonging to the other group to build starch and cellulose (see Figure 1 (b)). After the students had presented their works to the others, they were required to describe how starch and cellulose are used in plants. Figure 1 presents the pictorial analogy and the paper-clips model.

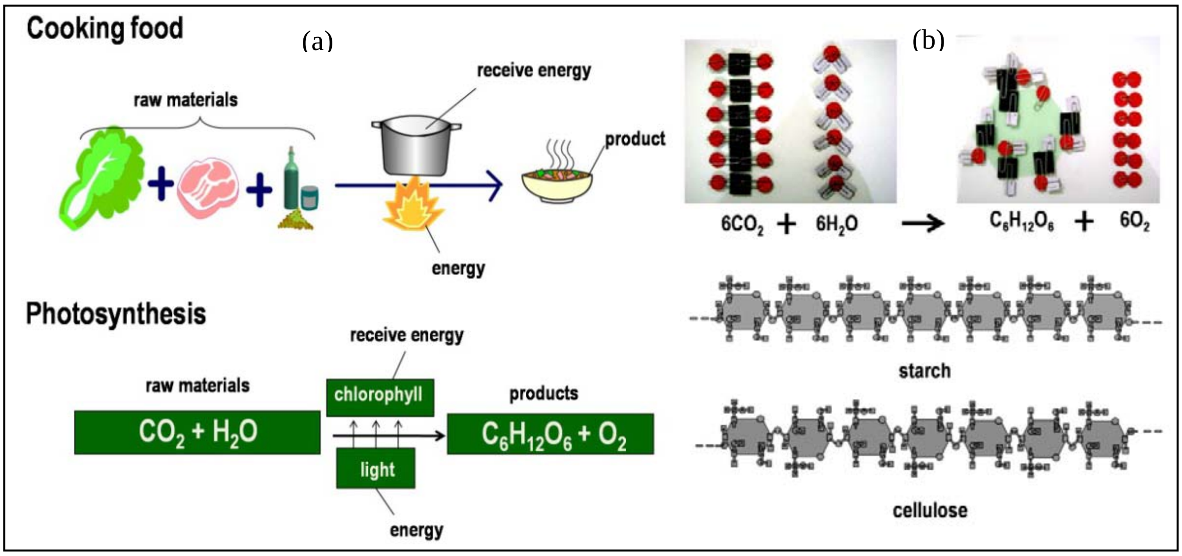

Figure 1. Pictorial analogy and photosynthesis paper-clips model.

Measure

Photosynthesis questionnaire developed by Marmaroti and Galanopoulou (2006) composes of 24 questions covering all aspects of photosynthesis. Four questions related to the content of this study were selected and used to determine students' prior knowledge about the origin of plant nutrients, the substances required for photosynthesis, the products of photosynthesis and the role of chlorophyll. The questionnaire was administered before and after the instruction and the students' responses were analyzed to describe how students' conceptions had changed over the instruction.

Results

In order to investigate how students' conceptions on photosynthesis had changed, we compared students' responses to the questions before and after the instruction. The frequencies of these responses are summarized in Figure 2.

According to the first question, "Which pair of substances is needed for photosynthesis", about 47.37% of students gave the correct answer in the pre-test. After the instruction, the percentage of the correct responses increased to 84.21%. In addition, the result in Table 1 showed that 41.38% of students had changed their conceptions from the alternative conceptions to the scientific one.

The second question asked students to choose a pair of substances produced during photosynthesis. The students tended to recognize the products of photosynthesis better than the raw materials. From pre-test scores, percentage of the correct answers was 61.40%, and it increased to 80.70% after the instruction (see Figure 2). In detail, 27.58% of the students had changed their responses from the alternative conception to the scientific one (see Table 2).

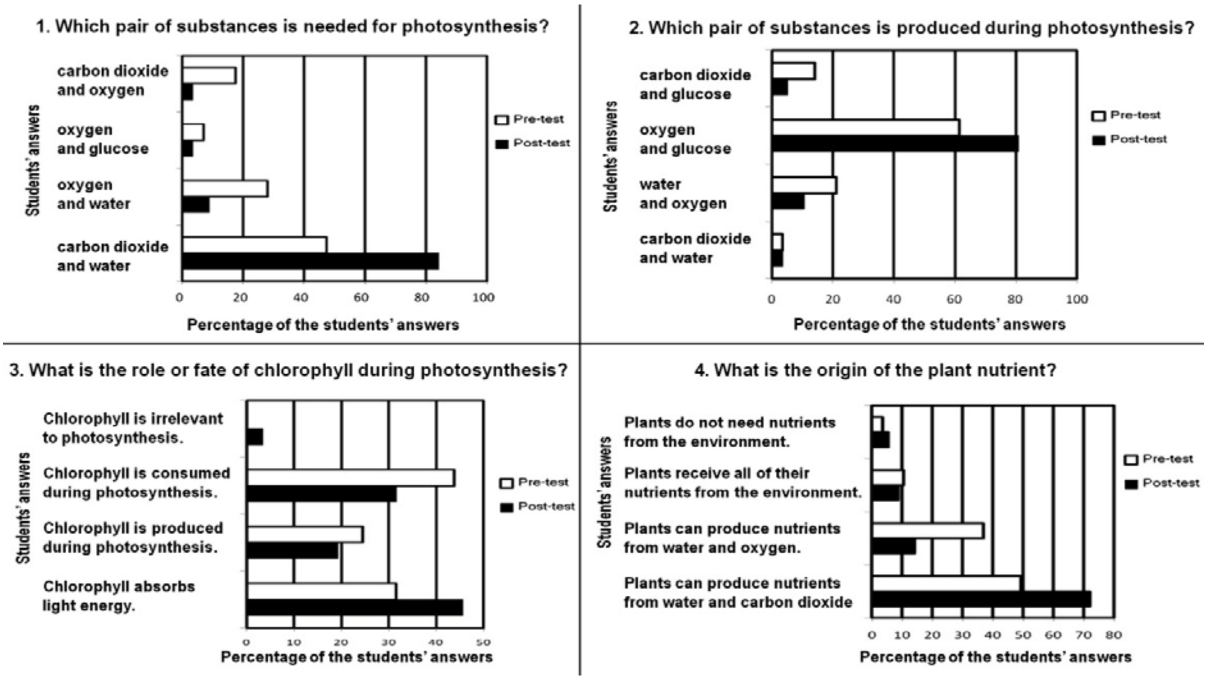

Figure 2. Comparison of students' responses to the questions before and after the instruction.

Table 1

The Percentage of Students Who Change Their Responses to the Question "Which Pair of Substances Is Needed for Photosynthesis?" After the Instruction

Responses	Percentage (%)
Changing from water and oxygen to carbon dioxide and water	22.41
Changing from oxygen and glucose to carbon dioxide and water	6.90
Changing from carbon dioxide and oxygen to carbon dioxide and water	12.07
Changing from carbon dioxide and water to water and oxygen	3.45
Changing from carbon dioxide and water to oxygen and glucose	1.72
Others	6.90

Table 2

The Percentage of Students Who Change Their Responses to the Question "Which Pair of Substances Is Produced During Photosynthesis?" After the Instruction

Responses	Percentage (%)
Changing from carbon dioxide and water to oxygen and glucose	3.45
Changing from water and oxygen to oxygen and glucose	13.79
Changing from carbon dioxide and glucose to oxygen and glucose	10.34
Changing from oxygen and glucose to carbon dioxide and water	1.72
Changing from oxygen and glucose to water and oxygen	3.45
Changing from oxygen and glucose to carbon dioxide and glucose	3.45
Others	3.45

Students' understanding of the role of chlorophyll in photosynthesis was determined by the third question. Before the instruction, only 31.58% of students gave the answer that chlorophyll absorbs light energy. After the instruction, the percentage of correct answer increased to 45.61% (see Figure 2), and 24.14% of students had changed their answers from the alternative conceptions to the scientific one (see Table 3). Interestingly, 10.34% of students who chose the scientific conception as the answer before the instruction had changed their responses to the alternative one (see Table 3).

Table 3
The Percentage of Students Who Change Their Responses to the Question "What Is the Role or Fate of Chlorophyll During Photosynthesis?" After the Instruction

Responses	Percentage (%)
Changing from chlorophyll is produced during photosynthesis to chlorophyll absorbs light energy	3.45
Changing from chlorophyll is consumed during photosynthesis to chlorophyll absorbs light energy	20.69
Changing from chlorophyll absorbs light energy to chlorophyll is produced during photosynthesis	5.17
Changing from chlorophyll absorbs light energy to chlorophyll is consumed during photosynthesis	1.72
Changing from chlorophyll absorbs light energy to chlorophyll is irrelevant to photosynthesis	3.45
Changing from chlorophyll is produced during photosynthesis to chlorophyll is consumed during photosynthesis	8.62
Others	1.72

The fourth question asked students to choose the statement corresponding to the origin of plant nutrients. Only 49.12% of students chose the correct answer before the instruction, and the number increased to 71.93% after the instruction (see Figure 2). 34.49% of students had changed their answers from the alternative conceptions to be the scientific one (see Table 4).

Table 4
The Percentage of Students Who Change Their Responses to the Question "What Is the Origin of the Plant Nutrient?" After the Instruction

Responses	Percentage (%)
Changing from the plant can produce nutrients from water and oxygen to the plants can produce nutrients from water and carbon dioxide	24.14
Changing from the plants receive all their nutrients from the environment to the plants can produce nutrients from water and carbon dioxide	6.90
Changing from the plant do not need nutrients from the environment to the plants can produce nutrients from water and carbon dioxide	3.45
Changing from the plant can produce nutrients from water and carbon dioxide to the plant can produce nutrients from water and oxygen	5.17
Changing from the plant can produce nutrients from water and carbon dioxide to the plants receive all their nutrients from the environment	3.45
Changing from the plant can produce nutrients from water and carbon dioxide to the plant do not need nutrients from the environment	3.45
Others	6.90

Discussion

The present study examined how students' conceptions on photosynthesis had changed after learning with analogy and model. It was expected that students would bring their ideas about raw materials needed, energy used, and the products of cooking food to understand photosynthesis as chemical reaction which composes of the reactants (carbon dioxide and water) and the products (glucose and oxygen). The result revealed that a great number of students (more than 80%) chose carbon dioxide and water as the reactants and glucose and oxygen as the products of photosynthesis after the instruction, even though most of them chose the distracters presenting alternative conceptions before the instruction. One explanation for this result is that analogy acts as a sense maker, making a new concept intelligible for the students and also a memory aid, when the physical objects or processes are used to explain biological processes (Venville & Treagust, 1996). Students are familiar with cooking food in which they need to use energy to make food from raw materials. This idea can be transferred to understand photosynthesis, since it also needs energy to transform the reactants to the products. Interestingly, students' understanding about the role of chlorophyll was improved in that chlorophyll is neither the reactants nor the products of photosynthesis. However, there were a number of students who changed their conceptions about the role of chlorophyll to be the alternative one. Some students thought that chlorophyll is irrelevant, because it was neither included in the photosynthesis equation (the target concept) nor cooking food process (analog). From this result, we realized that the students should be cleared not only about the similarity and difference between the analog and the target, but also the concepts related to the target concept.

Modeling photosynthesis activity extended the photosynthesis concept from using carbon dioxide and water to produce sugar to converting sugar to produce starch and cellulose. We expected that students should realize the usefulness of sugar as the nutrient for plant which can be used directly as the energy source or transformed into other substances. Before the instruction, only 49.12 % of the students thought that plant can produce nutrient from carbon dioxide and water. However, after learning from analogy and model, the number increased to 71.93 %. Again, we believe that the model help students understand biological process with the concrete physical objects as previously reported (Venville & Treagust, 1996).

Our findings have implications for both science educators and science teachers. The result of this study provide further evidence to support claims in the literature about using analogy and model in teaching for conceptual change. Moreover, it should be highlighted from the result of this study that students' understandings of photosynthesis can be improved through teaching with analogy and model.

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