Development of Conceptual Status Test to Examine Conceptual Change in Classrooms

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Abstract: Determining students' conceptual status can help teachers to examine whether conceptual change occurs in classrooms. Several methods such as interview and classroom observation have been used to examine conceptual status, but there were the considerations about the difficulty in classroom practice. The purpose of this study was to develop the conceptual status written test which allowed students to express their own ideas through their writing. In the test, students read an argument presenting the scientific conception and the alternative conception, and decide which explanation is more acceptable. If the scientific conception is intelligible, plausible, and fruitful in high level to the students, their responses will support the scientific conception. The conceptual status test was administered to 47 middle school students who had completed learning units on plant biology. The contents taught in the learning units were the same contents as in the test included cell function, photosynthesis, diffusion and osmosis. The reliability of test scores analyzed by using Cronbach's Alpha was .79. Item difficulty index ranked from 0.29 to 0.71, and item discrimination ranked from 0.29 to 0.75. The determination of student's conceptual status was reported and discussed.

Keywords: conceptual status, conceptual change model, written test

Introduction

Since the 1980s, the study of conceptual change teaching and learning has been developed in various theoretical frameworks. Duit and Treagust (2003) have reviewed research studies on conceptual change and defined conceptual change as "learning pathways from students' pre-instructional conceptions to the science concepts to be learned." Conceptual change learning includes adding new knowledge to preexisting knowledge without replacing the preexisting one, and restructuring the preexisting knowledge in order to understand the new knowledge. The best-known conceptual change model in science education was originated by George Posner, Kenneth Strike, Peter Hewson, and William Gertzog in 1982. In this conceptual change model, if the learner is dissatisfied with his or her prior conception and the new conception is intelligible, plausible, and or fruitful, accommodation of the new conception may follow. The new conception is intelligible, if it is non-contradictory and its meaning is understood by the student; plausible means that in addition to the student knowing what the conception means, he or she finds the conception believable; the conception is fruitful if it helps the learner solve other problems or suggests new research directions. The extent to which the conception meets these three conditions is termed the status of conception (Treagust. 2006: 26).

In order to determine the status of conception, it is necessary to have some communication from the students and have the statement from students to be analyzed. An analyst needs to take three steps in the determination of status (Hewson; & Hewson, 1992: 62). First, identify the representation of a conception from student's statement. Second, identify comments on the conception that are made by students related to the status of conception. Finally, interpret statements of representations and comments in term of their intelligibility, plausibility, and fruitfulness. The difficulty of this task depends on whether or not the person who makes the statements has used the conceptual change model technical language (intelligible, plausible, and fruitful).

Students' interview and classroom observation had been conducted in previous studies which intended to determine conceptual status. Hennessey (1991) conducted a classroom study which utilized technical classroom discourse analysis for determining status of students' conceptions. This study concluded that the students had the ability to use the technical terms of conceptual change model in classroom discourse. Lemberger (1995) utilized status determination for gathering evidence of students' conceptual learning and identifying the process of conceptual change. This study was conducted in a genetics course which was designed to provide an environment for students to pose problems and try to find the solutions for themselves. The method for determining status was non-technical classroom discourse in which the researcher conducted discourse analysis to interpret students' statements. This research found that student statements reflected explicit changes in the status of their conceptions of several important genetic concepts. Thorley (1990) developed discourse analysis categories for interpreting conceptual change in classroom discourse. Recordings were obtained from classrooms of three physics teachers addressing force and motion, and one life science teacher focusing on photosynthesis. Tsui and Treagust (2007) utilized Thorley's status analysis categories to determine the status of students' conceptions about genes. The authors used a case-based design with multiple data collection methods, and used an interpretive approach to analyze the data. The students in their study learned genetics in classroom lessons using the software BioLogica that provided multiple representations of gene. Results of the online tests and interview tasks revealed that most students improved their understanding of genetics. However, the analysis of students' status of gene conception indicated that only four students' post-instructional conceptions were intelligible, plausible, and fruitful.

From the literature above, determining students' conceptual status can help teachers to examine whether conceptual change occurs in classrooms. Several methods such as interview and classroom observation have been used to examine conceptual status, but there were the considerations about the difficulty in classroom practice. The purpose of this study was to develop the conceptual status written test which allowed students to express their own ideas through their writing. The Thorley's status analysis categories (1990) was adapted as the scoring criteria for evaluating students' responses. This test was expected for using in further conceptual change research and also in a classroom assessment.

Objectives

This paper aimed to describe the development of the conceptual status test to assess students' conceptual status of plant cell structures and functions, photosynthesis, diffusion and osmosis in plant transportation, and to discuss the students' responses regarding the status of conceptions.

Method

The conceptual status test consisted of 4 items in written open-ended format which allowed the students to express their own ideas in writing essays. The test contents which were consistent with the Thailand's Basic Education Curriculum B.E. 2551 included plant cell functions, photosynthesis, diffusion and osmosis in plant transportation. This test was the tool for evaluating student's conceptual status which includes the intelligibility, plausibility, and fruitfulness of the conceptions. The following sections described the subjects and the test development procedure.

Subjects

The subjects were 47 of lower secondary school students (grade 7) who had studied through the plant biology learning units of which the learning objectives were consistent with the objectives of the test.

The procedure of test development

The procedures of test development were as follow.

Step 1: Reviewing related literature concerning the status of conceptions to construct the operational definitions which consisted of the observable response, actions, tasks, or behaviors as an evidence of a construct. The operational definitions are presented in Table 1.

Table 1 The operational definitions for determining conceptual status (Thorley,1990)

the status of conception	operational definitions
Intelligibility	The scientific conception is intelligible to a student when he or she know what the conception means and can present this conception in different way.
Plausibility	The scientific conception is plausible to a student when he or she believe that it is true and really happen in nature.
Fruitfulness	The scientific conception is fruitful to a student when it achieves something that is valuable or useful for him/her.

Step 2: Determining tasks that can stimulate or reflect expected behaviors. Test items and scoring rubrics were also developed. The Thorley's status analysis categories (1990) was adapted as the scoring criteria for evaluating students' responses. Rubric was adopted to be scoring scale in order to determine whether or not the scientific conception was intelligible, plausible or fruitful to the students. In the test, students read an argument presenting the scientific conception and the alternative conception, and decide which explanation is more acceptable. If the scientific conception is intelligible, plausible, and fruitful in high level to the students, their responses will support the scientific conception. The example of test item is presented in Figure 1, and the scoring rubric is presented in Table 2.

Step 3: Examining content validity of the test. The conceptual status test was examined by two scientists and one science educator in order to gather evidence of test validity in term of the Item Objective Congruence (IOC). Each of the experts evaluated all of items and assigns a +1 if there was a strong match between the item and the objective provided, a 0 if the expert was uncertain, and a -1 if the item did not match the objective. The results of this rating were used to calculate the index value (Osterlind. 1998: 263). After all items had been examined by the experts, 3 items gained the index value more than 0.5 while one item gain IOC index = 0.33. Therefore, this item was revised considering the expert's comments.

Instruction: read the following essay and ideas of two persons, then think about your own idea and answer the provided questions.

Some plants have special stems that can storage food such as potatoes. Those stems store carbohydrate which provides energy for plants. It is very interesting to know how plants gain that carbohydrate. Student A and Student B have different ideas as follows:

Student A said " Plants transform minerals and water from the soil to carbohydrate. This carbohydrate is transported and storage in the stem" because student A noticed that plants which have enough mineral and water are healthy.

Student B said "Plants use light to transform carbon dioxide and water to carbohydrate. This carbohydrate is transported and storage in the stem" because student B noticed that plants which were placed in dark finally died.

Question 1. (Intelligibility)
With your own idea, how do the plants gain carbohydrate?
(Please explain clearly as much as you can. You can draw a picture
or give examples for your answer.)

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Question 2. (Plausibility)
Do you believe that your answer in question 1 really happens in nature?
If so, please provide the evidence that supports your answer as much as you can.

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Question 3. (Fruitfulness)
Does your idea contributed to the answer in question 1 has any implication?
If so, please give examples as much as you can.

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Figure 1 **the item that examines the conceptual status on photosynthesis**

Step 4: Trying out of the quality of the test items. The test was tried out with 47 middle school students who had studied through the plant biology learning units of which the learning objectives were consistent with the objectives of the test. The students' scores from this examination were analyzed to gain item difficulty index (*p-value*) and item discrimination (r) for each item (Osterlind, 1998). After the test had been tried out, item difficulty index ranked from 0.29 to 0.71, and item discrimination ranked from 0.29 to 0.75. The students' scores from this examination were also analyzed for the reliability of test scores. The result indicated that Cronbach's coefficient alpha (α) was 0.79.

Table 2 scoring rubric for item 1 considering the conceptual status on photosynthesis

score level	interpretation	descriptions
Intelligibility		
3	The scientific concept is intelligible in a high level.	Students give responses which are consistent with the student B's idea and use one of the following ways or more to present their conceptions - Use diagram or picture to represent the conception. - Use analogy or metaphor to represent the conception. - Use real world example to represent the conception. - Use linguistic or symbolic to represent the conception
2	The scientific concept is intelligible in a medium level.	Students give responses which are the same as the student B's idea and do not use their own word.
1	The scientific concept is intelligible in a low level.	Students give responses which are consistent with the student A's idea, or they express their alternative conceptions.
Plausibility		
3	The scientific concept is plausible In a high level.	Students use one of the following ways or more to give the reason why they believe that their conceptions is true and really happen in nature. - give the reason that indicates the consistency between scientific conceptions and laboratory data - give the reason that includes the causal explanation
2	The scientific concept is plausible in a medium level.	Students use one of the following ways or more to give the reason why they believe that their conceptions are true and really happen in nature. - give the reason that indicates the consistency between scientific conceptions and past experience. - give the reason that indicates the consistency between scientific conceptions and other conceptions
1	The scientific concept is plausible in a low level.	Students' responses indicate that the conceptions are uncertain.
Fruitfulness		
3	The scientific concept is fruitful in a high level.	Students use both of the following ways to give the reason why their conceptions achieve something of value for them. - express the applicability of the conception - give the statement includes something the conception might do in the future
2	The scientific concept is fruitful in a medium level.	Students use one of the following ways to give the reason why their conceptions achieve something of value for them. - express the applicability of the conception - give the statement includes something the conception might do in the future
1	The scientific concept is fruitful in a low level.	Students' responses can not be inferred that the scientific concept is useful to them, or the responses are not related to the question.

Results

Students' responses for each item were analyzed by the level of intelligibility, plausibility, and fruitfulness. We presented, in this paper, only the analysis of item 1 considering the conceptual status on photosynthesis. The result showed that even students had learnt photosynthesis, the percentage of students who acquired the high level of conceptual status was quite low. For the question 1, intelligibility question, 21 percent of students showed that the scientific concept is intelligible in a high level for them, while 23 percent of students expressed that the scientific concept is intelligible in a medium level. Interestingly, the percentage of students who held alternative conceptions was 54 %. Table 3 presents students' responses and their interpretation.

Table 3 students' response regarding the intelligibility of the scientific concept

students' responses	interpretation	percentage of students
1. Plants have photosynthesis process and gain sugar which is carbohydrate. 2. Plants gain carbohydrate from photosynthesis process by using carbon dioxide and water. The products of photosynthesis are sugar and oxygen. Then, plants transport carbohydrate through transport tissue to other parts. 3. Plants gain carbohydrate from photosynthesis which is like cooking food.	The scientific concept is intelligible in a high level.	22
4. Plants use light to transform carbon dioxide and water to carbohydrate. This carbohydrate is transported and storage in the stem. (students do not use their own word)	The scientific concept is intelligible in a medium level.	23
5. Stem absorbs water and minerals, and those materials transform to be starch or sugar and oxygen. 6. Plants use their root to find minerals and water as much as they can in order to make carbohydrate. 7. Plants gain carbohydrate from fertilizer. 8. Plants gain carbohydrate from the soil and light.	The scientific concept is intelligible in a low level.	55

For the question 2, plausibility question, only 8 percent of students showed that the scientific concept was plausible in a high level. 29 percent of students showed that the scientific concept was plausible in a medium level. Finally, 60 percent of students' response indicated that the scientific concept was plausible to the students in a low level. Table 4 displays the students' responses and the interpretation.

Table 4 students' response regarding the plausibility of the scientific concept

students' responses	interpretation	percentage of students
1. It is true because I have already done the experiment. 2. I have seen in the experiment that plant could not make carbohydrate without light. 3. The raw material of photosynthesis is carbon dioxide, and minerals are not raw material for making carbohydrate. 4. The way plants make carbohydrate is like cooking food which requires raw material. Raw materials of photosynthesis are carbon dioxide and water, not minerals.	The scientific concept is plausible in a high level.	9
5. It is true because plants will die if they have not enough light. 6. It is true because plants need water, carbon dioxide, and light	The scientific concept is plausible in medium level.	30
7. I'm not sure that it really happens in nature. I have never seen it before. 8. It is uncertain. I'm not sure	The scientific concept is plausible in low level.	61

The question 3 asked students to express their ideas considering the fruitfulness of the scientific concept. The result indicated that only 4 percent of students showed that the scientific concept was fruitful in a high level. 33 percent of students showed that the scientific concept was fruitful in a medium level. Finally, 60 percent of students' response indicated that the scientific concept was fruitful to the students in a low level. Table 5 displays the students' responses and the interpretation.

Table 5 students' response regarding the fruitfulness of the scientific concept

students' responses	interpretation	percentage of students
Students use both of the following ways to give the reason why their conceptions achieve something of value for them. 1. give the statement includes something the conception might useful in the future - The scientific concept is useful for a career such as a farmer or a teacher. - It is useful for my study in the future 2. express the applicability of the conception - It helps me understand how plants gain carbohydrate and store in the tuber. - This concept help me understand why plants die when they are not exposed to light.	The scientific concept is plausible in a high level.	4
3. Students use one of the ways presented above to give the reason why their conceptions achieve something of value for them.	The scientific concept is plausible in a medium level.	34
4. Students' responses are not related to the question: for example, carbohydrate provides energy for all living things.	The scientific concept is plausible in a low level.	62

In conclusion, the result of test development was described, and the examples of students' response were reported. The reliability of test scores analyzed by using Cronbach's Alpha was .79. Item difficulty index ranked from 0.29 to 0.71, and item discrimination ranked from 0.29 to 0.75. The result of student's responses to item 1 indicated that about more than half of students (55% - 62%) showed that the scientific concept was intelligible, plausible and fruitful for them in a low level.

Discussion and recommendation

From data collected in this study, about half of the students express that photosynthesis concept was intelligible, plausible and fruitful in a low level. This result was consistent with previous studies. Aleixandre; et al. (1996) have summarized the results of studies on students' alternative conceptions related to photosynthesis, and concluded that two specific alternative conceptions were found in most studies; their incidence spans across ages and cultures. The alternative conceptions are that: 1) plants obtain organic materials (food) from the soil, and 2) photosynthesis is the respiration of plants. Stavy; et. al. (1987) suggested that students who have the idea that plants obtain organic materials from the soil might be referring to organic fertilizers.

The result of this study leads to the revision of learning experience provided to the students. To raise the status of scientific concept, the learning activity should provide more accessible explanation of scientific concept, more evidence to support the concept, and more application of the concept. Hewson; Beeth; & Thorley (1998) proposed teaching for conceptual change in that activities aimed at raising the status of particular ideas should be a part of teaching for conceptual change. The objectives of these activities might be constructed to present and develop the ideas, to provide examples of them, to apply them to other circumstances, to give different ways of thinking about them, and to link them to other ideas. Activities aimed at lowering the status of other ideas also should be a part of teaching for conceptual change. These activities might aim to explore their unacceptable implications, to consider experiences which they are unable to explain, or to find ways of thinking about them that point to their inadequacies.

The conceptual status test can also be used in classroom practice to determine types of conceptual change occurred after learning experience if the test is administered before and after the instruction. There are two kinds of conceptual change. The first kind of conceptual change happens when the students change their ideas from alternative conceptions to be the scientific one. This kind of change is called conceptual exchange. On the other hand, conceptual capture happens when the students already hold the scientific conception and it changes to be more intelligible, plausible and fruitful.

Hewson and Hewson (1992) argued that investigating the status of student's conceptions is important in various ways. First, their investigation provides a powerful method of analyzing instruction, whether or not it was designed based on the conceptual change model. Second, it provides valuable techniques for a teacher who wants to influence the course of conceptual change in their students. Third, it opens up new instructional possibilities by introducing status as an explicit part of classroom discussion. Finally, it provides evidence to support or deny the conceptual change model's assertions for researcher to test this model. In addition, Lemberger (1995) claimed that the evidence of conceptual change learning can be derived from learners' statements that are related to the status of their conceptions.

In addition to using the conceptual status test to improve teaching in class, this test can also be used in further study on conceptual change research. The further study could be conducted by examination the change of student's conceptual status after learning with various teaching approaches.

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