Modelling-based Teaching: A Strategy to Enhance Students' Understanding of Model in Science

การจัดการเรียนรู้ด้วยการสร้างแบบจำลอง: กลวิธีส่งเสริมความเข้าใจของนักเรียนเกี่ยวกับแบบจำลองในวิทยาศาสตร์

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ABSTRACT

This study was a pre-experimental research aimed to compare students' understanding of models before and after implementation of the modelling-based teaching. There were 34 participants involved in this study and studied in grade 7. The research instrument used to evaluate students' understanding of models was questionnaire adopted from a previous study. This questionnaire was translated from the English to Thai version and the reliability was also checked by science education experts. Students' responses from the questionnaire were analyzed to compare a mean score in the pretest and posttest by using paired sample t-test. The research findings showed that the posttest score was statistically significantly higher than the pretest score ($p < 0.05$). This suggests that the MBT provides students with great opportunity to develop their understanding of scientific models in science learning.

บทคัดย่อ

การศึกษาครั้งนี้เป็นการวิจัยแบบก่อนการทดลอง ซึ่งมีจุดประสงค์เพื่อเปรียบเทียบความเข้าใจของนักเรียนเกี่ยวกับแบบจำลองในวิทยาศาสตร์ระหว่างก่อนเรียนและหลังเรียนโดยใช้การจัดการเรียนรู้ด้วยการสร้างแบบจำลอง ผู้เข้าร่วมการวิจัยคือนักเรียนชั้นมัธยมศึกษาปีที่ 1 จำนวน 34 คน เครื่องมือที่ใช้ในการวิจัยคือแบบสอบถามความเข้าใจของนักเรียนเกี่ยวกับแบบจำลองในวิทยาศาสตร์(SUMS) ฉบับภาษาไทยซึ่งตรวจสอบความเชื่อมั่นโดยผู้เชี่ยวชาญ วิเคราะห์ข้อมูลโดยคะแนนค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน และทดสอบความแตกต่างระหว่างคะแนนก่อนเรียนและหลังเรียน โดยใช้ Paired sample t-test ผลการวิจัยพบว่า นักเรียนมีคะแนนความเข้าใจเกี่ยวกับแบบจำลองทางวิทยาศาสตร์เฉลี่ยหลังเรียนสูงกว่าก่อนเรียนอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 ผลการวิจัยนี้แสดงให้เห็นว่าการจัดการเรียนรู้ด้วยการสร้างแบบจำลองช่วยพัฒนาความเข้าใจของนักเรียนเกี่ยวกับแบบจำลองทางวิทยาศาสตร์ในการเรียนรู้วิทยาศาสตร์

KeyWords: Modelling-based teaching, Student's understanding of models in science

คำสำคัญ : การจัดการเรียนรู้ด้วยการสร้างแบบจำลอง ความเข้าใจของนักเรียนเกี่ยวกับแบบจำลองในวิทยาศาสตร์

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Introduction

Scientific models are used in classrooms to explain abstract concepts which are difficult to observe directly and to predict the behavior of objects or system in the real world. In other words, they provide representations of scientific concepts that can make the difficult ideas more easily understandable to students (Chittleborough, Treagust, 2009). Modelling is a central component of modern science which helps students to learn the nature of science. Therefore, involving students in scientific modelling is a way to enable learners to appropriate practices as a part of scientific literacy (Schwarz, 2009) – it is a core process in science learning which helps students to develop and reflect their understanding via constructed, used and evaluated to revising of their mental models. Experience with constructing of models help students to develop their own mental models of scientific concepts and developing scientific knowledge (Treagust et al., 2002). Although models are frequently presented in the textbooks and used by teachers in science classrooms, unfortunately, the role of the models to explain phenomena and to be tools within scientific process in the real situation is not greatly concerned (Namdar, Shen, 2015; Schwarz, 2009). Thus, the significance of model and modelling should be taught and practiced through schooling. Accordingly, students' understanding of scientific models has been a part of science learning in which an important element of scientific literacy is encouraged (Treagust et al., 2002).

Global warming is one of the important environmental problems which its dangerous effects are increasing gradually and students' perception outcomes have misconception about it (Çimer, et al., 2011), because there were abstract complex topics in middle school and difficult to understand, e.g. different types of radiation and their interaction with the Earth's surface; gases and clouds in the atmosphere; and the relationship between the greenhouse effect and temperature (Kukkonen, 2014). To engage students in such practice, modelling-based teaching (MBT) is a focused teaching strategy which enables to support them to work scientifically (Justi, 2009). In learning activities of MBT were drawing and writing on modelling in paper model as researcher's method was perceive and focused on student's mental model from learning (Libarkin et al., 2015). Students could express their concepts via modelling and test their models through scientific experiment about greenhouse effect and then revise their models which this process could construct students' understandings.

This research study aimed to investigate the impact of MBT on students' understanding of model of greenhouse effect which is a vital topic relating to environmental issue. Science education aims to prepare students to be scientific literate citizen, it is thus needed to promote them to have knowledge about global warming and climate change (Shepardson et al., 2011).

Background

Modelling-based teaching (MBT)

Modelling-based teaching (MBT) is an instructional approach that enables to support the development of scientific knowledge (Justi, 2009). In order to enhance scientific modelling based on this approach, students should get experience in thinking and reflecting of their thinking via constructed, used, and evaluated to revise the expressed mental models. The MBT consisted of four steps. First is production of mental model. Within this, students are

required to – decide on purpose, have experience, select source for model, and produce their own mental model. Second is an expression of models - it is the dynamic and creative process of interaction from the first step results in the elaboration of a mental model that must be expressed in an adequate mode of representation. Third is testing of models - within this step, students are asked to perform a science experiment in order to test their expressed models. Last is consideration of scope and limitation of model. It is very essential for students' learning. After the conclusion, students attempted to persuade their colleagues and/or their teachers to evaluate their expressed models which previously constructed at the beginning of lesson. If there are some limitations in their models, they have to revise their models. This leads to a reconsideration of the earliest elements of the modelling process.

Student's Understanding of Model in Science (SUMS)

Student's Understanding of Models in Science (SUMS) is a questionnaire which originally designed and developed by Treagust et al. (2002). It is a 27-item questionnaire which requires students to respond on a five Likert-type scale, i.e., strongly disagree, disagree, not sure, agree, and strongly agree. Distinct themes in the items of the SUMS instrument cover the following scales: 1) the models as multiple representation (MR) scale explores students' acceptance of using a variety of representations simultaneously and their understanding of the need for this variety, 2) the models as exact replicas (ER) scale refers to students' understanding of how a model closely approximate the real thing, 3) the models as explanatory tools (ET) scale refers to what a model can help students understand an idea in science, 4) the uses of scientific models (USM) scale explores students' understanding of how models are able to use in science in terms of descriptive and explanatory purposes, and 5) the changing nature of models (CNM) scale addresses the permanency of models in science.

Objective of the study

This study aimed to investigate the impact of MBT on students' understanding of model in greenhouse effect. More specifically, the research question was that: is there any difference of students' understanding of models in greenhouse effect before and after participating in MBT?

Materials and Methods

Research design

A pre-experimental research, particularly one group pretest-posttest design, was adopted (Campbell et al., 1963). This research aimed to examine the effect of MBT on student's understanding of scientific models in greenhouse effect.

Participants

Participants in this study were grade 7 students who studied at the rural middle school. They were 12–13 years old, who studied in the second semester of 2016 academic year. All of them had not been taught greenhouse effects and had no experience with learning MBT.

Intervention

The greenhouse effect unit was developed for seventh graders by using the MBT framework. The unit comprised three lessons (i.e., 1) the effect of the sun's rays on global temperature change, 2) the effect of the atmosphere layers on global temperature change, and 3) the effect of the greenhouse gas on global temperature change. Before implementation of the MBT, the students were asked to investigate an understanding by using questionnaire – the SUMS. All three topics were designed to allow them to carry out an experiment and use evidence in order to explain the dynamic interaction of factors on the global temperature and to describe central mechanism of greenhouse effect. The main objective of three lessons required the students to create their own models to represent their understandings of the greenhouse effect. The sequence of the MBT required them to practice modelling process as shown in Table 1. The first step was designed to encourage them to think about their mental models. They were asked to draw, label important keywords, and write their understandings on greenhouse effect. During the second step, they were required to present their own models to share ideas among their classmates. Next, they tested their models through carrying out a science experiment in small groups and presented the results. Finally, they discussed their models to be a representation of the greenhouse effect and revised their models again.

Table 1 The impact of MBT on modelling process and scientific understanding of models in science

Lesson 3: The effect of greenhouse gas on global temperature change.		
Steps of MBT	**Modelling process**	**SUMS scale**
Learning objective: To draw a model and explain about the effect of the greenhouse gas on global temperature change.		
Step 1: Production of mental model	Models constructing	MR, ER, ET, USM
Step 2: Expression of the model	Models presenting	MR, ET, USM
Step 3: Testing of the model	Models testing	ER
Step 4: Consideration of scope and limitation of model	Models revising	MR, ER, ET, USM, CNM

After the instructional intervention, the greenhouse effect unit was taught for three weeks and the students were asked to investigate their understanding using the same questionnaire.

Instrument

As mentioned earlier, the SUMS questionnaire had 27 items which was Likert-type scale, i.e., 1=strongly disagree, 2=disagree, 3=not sure, 4=agree, and 5=strongly agree. It was translated from English to Thai version. This translation was approved by an expert English teacher to examine the validity of language and revised based on her comments and suggestions. Then the revised translated version was sent to science educators to evaluate the validity of content. After this revision, the SUMS was trial out with 76 students, 7 grade students – a group of students who had similar characteristic with the participants. It was found that the Cronbach alpha reliability was 0.83 which was acceptable (Gliem, Gliem, 2003) (see Table 2).

Table 2 Descriptive statistics and reliability of the SUMS (n = 76).

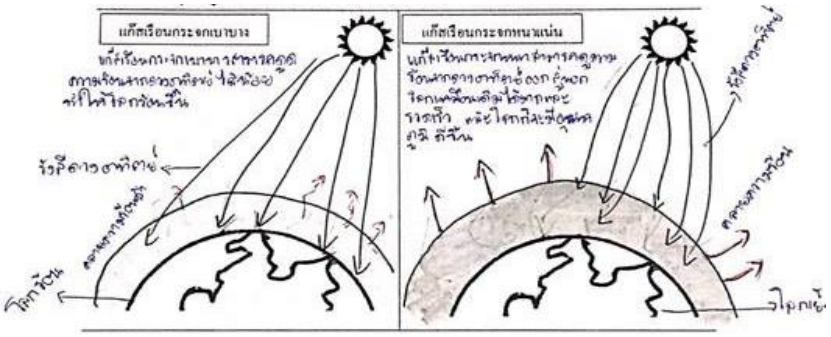
Instrument	Number of items	Mean	S.D.	Cronbach alpha reliability
Student Understanding of Model in Science	27	4.06	0.32	0.83

Data collection and data analysis

In order to answer the research question, the participants were asked to do the SUMS before getting started the instructional intervention. Students took about 30-40 minutes to complete this questionnaire. The greenhouse effect unit was started with the orientation and followed by three lessons which placed emphasis students on modelling process. Again the same questionnaire was administered to them after completing the intervention. Data from the pretest and posttest helped the researcher to gain insight into the students' understandings of the role of scientific models when they participated in MBT. To compare the results from the SUMS, the Statistical Package for Social Scientists (SPSS) version 17.0 was used the paired samples t-test was determined whether the mean of the differences between the posttest and pretest score of the SUMS (see Table 3).

Results

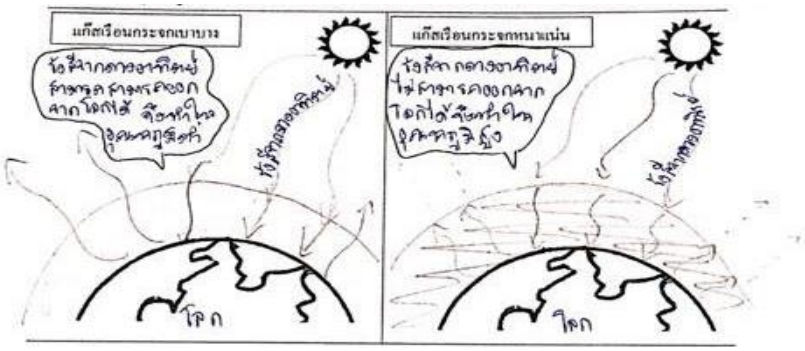
As mentioned earlier, the students were taught by MBT to gain insight into students' understanding of the role of models in learning science. For example, the last MBT lesson was related to the effect of greenhouse gas on global temperature change in Figure 1 and Figure 2.



[A; the small amount of greenhouse gas] [B; the large amount of greenhouse gas]

Figure 1 Example of a student's initial model

In Figure 1 showed that, a student's initial model showed that her scientific model was incomplete – she misunderstood that a layer of the small amount of greenhouse gas would result in increased temperature on the earth. Thus the temperature in Figure 1A was higher than 1B. In contrast to the revised model, she understood scientific concept correctly.



[A; the small amount of greenhouse gas] [B; the large amount of greenhouse gas]

Figure 2 Example of a student's revised model.

In Figure 2 showed that, her revised model was more complete than the initial one. She learnt that, at a layer of small amount of greenhouse gas, sun's rays would radiate back into atmosphere, whereas at a layer of large amount of greenhouse gas would trap heat and store up energy. Temperature on the earth in Figure 2A is lower than 2B.

To compare mean score of students' understandings of models before and after implementation of MBT, the normal distribution between the paired values were checked and these values were approximately normally distributed. Thus, the paired sample t-test was used as shown in Table 3.

Table 3 Paired sample t-test comparison between pretest and posttest.

Group	N	Mean	SD.	T
Pretest	34	4.10	0.27	-7.831*
Posttest	34	4.50	0.25	

*$p < 0.05$

From table 3 showed that, overall, there was statistically significance difference between the mean score in the posttest and pretest ($p<0.05$).

Discussion and Conclusion

Results from data analysis showed that the students' initial models showed that their scientific models were incomplete. But, after learning in MBT, their revised models were more complete than the previous initial models. Therefore; the MBT was able to support students' understanding of scientific model of greenhouse effect, and the mean score of students' understandings of models before and after implementation of MBT, Overall, there was statistically significance difference between the mean score in the posttest and pretest ($p<0.05$). This suggests that MBT activities could help students to learn how the role of scientific models is, e.g., model can be used to describe scientific phenomena (Buckley, 2012).

In addition, modelling process underlying an idea of MBT showed that students changed their understanding and expressed in terms of models in greenhouse effect. An initial model presented before carrying out an experiment showed misconception, but a revised model revealed scientific views. It could be claimed that all MBT activities sufficiently supported the process of model construction, model using, and model evaluation. More specifically, students' communication of each model to the whole class during model evaluation is useful for them to revise their initial (Maia, Justi, 2009). Similar to the findings of Krell et al. (2014), this study suggests MBT provided the students opportunities to understand scientific models in each step e.g., expression of models allowed them to learn MR, ET, and USM, respectively, as mentioned in Table 1.

This research study focused on learning activities with supporting the students to understand the importance of model and modelling in learning science. Based upon the results from this study, when implementing MBT, many students had the better understanding of the role of scientific models in studying greenhouse effect which is an important topic at the middle school level. It could be concluded that MBT was a strategy which enabled to enhance students' understandings of models. Such understanding will serve as a mechanism to prepare students to have scientific knowledge on environmental issue. Moreover, science teachers should use model more routinely in the classrooms in order to provide inspiration for their students to understand the nature of scientific work.

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