Using hands-on activity approach to design mathematical modeling-based learning for promoting grade 9 students’ mathematical modeling competency

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Abstract
Learning in the mathematics classroom emphasizes the content, the thinking process, and the skills required that is aimed primarily at helping students apply what they have learned to solve everyday problems. However, most students have succeeded in only solving specific mathematical problems but when they face common problems, they cannot handle them. One of the mathematical methods used when dealing with non-mathematical problems is mathematical modeling. The mathematical modeling process transforms a general problem into a mathematical problem and then solves problems and interprets the results to answer the original problem. By this result, promoting students’ modeling competency is very important. This research develops a learning model called as Mathematical Modeling-Based Learning (MMBL) with hands-on activity approach to develop the students’ modeling competency and we had verified the significant effect that Mathematical Modeling-Based with hands-on activity approach had an effect on the student’s mathematical modeling competency.

Keywords: Hands-on Activity Approach, Mathematical Modeling, Mathematical Modeling-Based Learning, Mathematical Modeling Competency

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1 Introduction

Learning in the mathematics classroom emphasizes the content, the thinking process, and the skills required. This is aimed primarily at helping students apply what they have learned to solve everyday problems. However, most students have succeeded in only solving specific mathematical problems but when they face common problems, they cannot handle them. This is an issue that must be taken into account in the classroom management in mathematics (Kaiser, G., Blum, W., Ferri, R. B., & Stillman, G. (Eds.), 2011; Schoenfeld, A. H., 2013; Schoenfeld, A. H., 2013; Burkhardt, H., 2013).

One of the mathematical methods used when dealing with non-mathematical problems is to create mathematical models. The mathematical modeling process is the way to transform a general problem into a mathematical problem and then use mathematical methods to solve problems and interpret the results to answer the original problem. By this result, promoting students’ modeling competency is very important and modeling competency may be called as applied problem-solving skill. If students were cultivated with modeling competency, students would have the ability to solve common problems in real life (Kaiser, G., Blum, W., Ferri, R. B., & Stillman, G. (Eds.), 2011; Chan, E. C. M., Ng, D. K. E., Widjaja, W., & Seto, C., 2012; Schoenfeld, A. H., 2013; Schoenfeld, A. H., 2013).

To promote students’ modeling competency in mathematics classroom learning, students should be trained to create mathematical models (Schoenfeld, A. H., 2013; Schoenfeld, A. H., 2013; Blum, W., 2013; Ferri, R. B., 2013). This research develops a learning model called as Mathematical Modeling-Based Learning (MMBL) with hands-on activity approach. This will help develop the students’ modeling competency through activity with equipment that are used to practice as well as doing laboratory.

Figure 1. Diagram showing the importance, approach, and goal
Key Concept of Mathematical Modeling-Based Learning with Hands-on Activity Approach

For the development of mathematical modeling-based learning (MMBL) with hands-on activity approach, seven stages of modeling process from Anhalt, C. O., & Cortez, R. (2015) were applied. Instructional materials called as hands-on activity approach would be played as a scaffolding tool for support students to perform in the stage of modeling process that motivated students to employ modeling competencies with problem situations with hands-on activity approach. All of stages could be summarized in Figure1 and could be given by details of each stage as follow.

Stage 1: Analyze the Situation or Problem
1a) Identify problems from the external context (Mostly from everyday context) looking for answers or situation to understand and explain.
1b) Find more relevant information if needed.
1c) Make the situation or problem is reasonable and understand the question.

Stage 2: Develop and Formulate a Model
2a) Specify all required information.
2b) Identify the basic assumption needed.
2c) Converting the information provided in the problem together with the initial assumption into a mathematical problem which can find the answer.
2d) Use appropriate mathematics for the given data.

Stage 3: Solve or Compute a Solution of the Model
3a) Find the mathematical solution problems identified in the model.
3b) Analyse and implement the model.
3c) Check the correctness

Stage 4: Interpret the Solution and Draw Conclusions
4a) Interpreting mathematical solutions in terms of original situation.
4b) Construct a conclusion, where the solution indicates the original situation.
**Stage 5: Validate Conclusions**

5a) Reflects that the mathematical answer is sensible in terms of the original situation (i.e., the value is in the actual sensible range).

5b) If the appropriate conclusions are consistent, consider the accuracy of the solution statement. If it does not fit properly or needs to be improved, go back to step 2 again (create and customize).

**Stage 6: Develop and Formulate a New or Modified Model**

6a) Modify the initial assumption, which follows what we know about the first solution, and transforms it into a new mathematical problem, or a new one to solve the problem.

6b) The relevant mathematical knowledge may differ from the first we perform.

6c) Perform various steps, including computation, interpretation, and re-examination.

**Stage 7: Report the Solution**

7a) Present conclusions and arguments related to joint conclusions.

And from the 7 stages of the learning process of Modeling can be classified into three levels as follows.

**Structured Modeling**

Students follow the step-by-step process in each element that is defined. This level of Modeling is great for practicing and building on Modeling competencies before stepping into a more self-practice.

**Guided Modeling**

Students follow the step-by-step process in each element that provides the right advice for students. This level model is ideal for students who have some kind of Modeling performance already.

**Opened Modeling**

Students conduct a step-by-step process in each element based on the student’s concept. Creating this model is ideal for students with sufficient performance-related abilities.

For this research, it will be designed as a modeling learning, through hands-on activity approach, in which the design of the activity begins with structured modeling in the early plan, and then gradually becomes more guided modeling and finally becomes opened modeling.
3 Methodology

Participants
This study was designed to investigate the effect of using hands-on activity approach to create Mathematical Modeling-Based learning (MMBL) to students’ modeling competency. The subjects were 32 ninth grade students from Buntharikwittayakarn school, Ubon ratchathani Province, Thailand, in the academic year 2559.

Instruments
There were 5 lesson plans in incorporate content up to a maximum of ninth grade. Each MMBL was designed to support student to use modeling competency to perform modeling process through hands-on. To investigate the effect of using MMBL on the levels of students’ modeling competency, the subjective tests were created. The rubrics for scoring subjective tests based on essential features of modeling competency related were developed. In the rubric, each of the six levels of modeling competency applied from Gatabi, A. R., & Abdolahpour, K. (2013) and Leong, K. E. (2013) were defined and the following criteria.

- Level 0: The student has not understood the situation and is not able to sketch or write anything concrete about the problem.
- Level 1: The student only understands the given real situation, but is not able to structure and simplify the situation or cannot find connections to any mathematical ideas.
• Level 2: After investigating the given real situation, the student finds a real model through structuring and simplifying, but does not know how to transfer this into a mathematical problem (the student creates a kind of word problem about the real situation).
• Level 3: The student is able to find not only a real model, but also translates it into a proper mathematical problem, but cannot work with it clearly in the mathematical world.
• Level 4: The student is able to pick up a mathematical problem from the real situation, work with this mathematical problem in the mathematical world, and have mathematical results.
• Level 5: The student is able to experience the mathematical modeling process and validate the solution of a mathematical problem in relation to the given situation.

Procedures
A total of 32 ninth grade students involved in this study were engaged in MMBL with hands-on activity approach. The subjective tests were administered as posttest to students. The rubric score was employed to determine the level of students’ modeling competency through their performing in subjective tests.

Data analysis
Data from rubric for evaluating student’ modeling competency were analyzed using descriptive statistics to find frequency of students identifying particular student’ modeling competency levels.

4 An Example of Mathematical Modeling-Based Learning with Hands-on Activity Approach

Students were separated in 5-6 people per group by using equal ability criterion for each group. There were five groups to perform learning activities of each learning stage hereinafter.
Situation

To build a house on a one acre, but before you build a house, you want to make a house fence around it. If the house is rectangular, what is the width and length that it will save money on fencing?

Stage 1: Analyze the Situation or Problem

What is the problem?
The problem provides area of rectangle for building a house and the students are asked to determine width and length that minimize perimeter of rectangle. Students may be motivated by additional questions such as:

Width and length, are they necessary that only integers?

What happened when the area changes?

What is the preferred answer?
The preferred answer is the interpretation of the minimum value of width and length in the form of the lowest fence building price.

Stage 2: Develop and Formulate a Model

Students are motivated by the question of what variables or parameters are involved. This situation includes the following variable:

\[ a = \text{The width of the rectangle, which is the area of the house} \]
\[ b = \text{The length of the rectangle, which is the area of the house} \]
\[ A = \text{The area of the rectangle, which is the area of the house} \]
\[ P = \text{The perimeter of the rectangle, which is the length of the house fence}. \]

Students develop the following models.

\[ A = ab \] \hspace{1cm} (1)

\[ P = 2a + 2b \] \hspace{1cm} (2).

Students work on models using tables and graphs from table values. For this learning activity, mathematical models are seen as relation, values of the tables, and graphs from the values of the tables.

Stage 3: Solve or Compute a Solution of the Model

Students consider the values of the tables and graphs in order to arrive at the conclusion that the shortest fence should be wide and long.

Stage 4: Interpret the Solution and Draw Conclusions

Students interpret the width and length of the rectangle in the meaning of the house fence and conclude the shortest fence.

Stage 5: Validate Conclusions

From the mathematical model, it is advisable to know that the quadrilateral should be square enough to give the smallest perimeter, which means that the fence to be constructed is of the least length, as a result, it is the most economical price.

Stage 6: Develop and Formulate a New or Modified Model

At this stage, the students may be motivated by determining the condition of the house area as a different geometry. Or use the original image to conclude that the square is the shortest line by giving students observes the change in area size like this lesson plan.
Stage 7: Report the Solution

Students share results and conclusions, and explain why results and conclusions can be derived.

Figure 5. This image is from a learning activity using MMBL. The picture (a) is about the device of hands-on activity used to think about modeling. For the picture (b), it is a work of mathematical modeling through MMBL learning with hands-on activity approach.

5 Mathematical Modeling Competency from Mathematical Modeling-Based Learning with Hands-on Activity Approach

The observation of students’ modeling competency from the support of Mathematical Modeling-Based Learning with hands-on activity approach would be determined by the subjective tests after the instructional sequence had been finished. Problem situation in the subjective test said that “A car registration company wants to produce a car registration consisting of letters and numbers. It consists of 2 alphabets that chose from A-Z and 3 numeric characters that chose from 0-9, Letters and numbers can be duplicated, such as AA123 AB334. Want to know how much the company can produce all car registrations”. After the students have created the mathematical model followed by the learning process using mathematical modeling, the results show that the modeling performance of the learners is summarized in Figure 6.
Level 0: The student has not understood the situation and is not able to sketch or write anything concrete about the problem.

Level 1: The student only understands the given real situation, but is not able to structure and simplify the situation or cannot find connections to any mathematical ideas.

Level 2: After investigating the given real situation, the student finds a real model through structuring and simplifying, but does not know how to transfer this into a mathematical problem (the student creates a kind of word problem about the real situation).

Level 3: The student is able to find not only a real model, but also translates it into a proper mathematical problem, but cannot work with it clearly in the mathematical world.

Level 4: The student is able to pick up a mathematical problem from the real situation, work with this mathematical problem in the mathematical world, and have mathematical results.

Level 5: The student is able to experience the mathematical modeling process and validate the solution of a mathematical problem in relation to the given situation.

Figure 6 show that there are no students with lower level of mathematical modeling competency than level 4. There are 56% students who have the mathematical modeling competency to build up to level 4 and there are 44% students who have the mathematical modeling competency up to level 5. This means that 56% students are able to pick up a mathematical problem from the real situation, work with this mathematical problem in the mathematical world, and have mathematical results. The example of student work at this level is shown in Figure 7.
Moreover for 44% students in level 5, this mean that they are able to experience the mathematical modeling process and validate the solution of a mathematical problem in relation to the given situation. The example of their work at this level is shown in Figure 8.
6 Summary

Concerning our study goals, the attempt to explore the supportive use of Mathematical Modeling-Based with hands-on activity approach on the student’s mathematical modeling competency, we had verified the significant effect that Mathematical Modeling-Based with hands-on activity approach had an effect on the student’s mathematical modeling competency. The students learned about creating a mathematical model using Mathematical Modeling-Based with hands-on activity approach make the modeling competency of the students be promoted. This modeling competency will provide students with applied problem-solving skills that students can use this skill to deal with real problems in everyday life.

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References


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