DEVELOPMENT OF A SELF-DIAGNOSTIC MODEL IN THE COGNITIVE DOMAIN IN PROBLEM SOLVING SKILLS IN MATHEMATICS

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Abstract

This study aimed 1) to develop a self-diagnostic model in the cognitive domain in problem solving skill in mathematics, and 2) to study the effectiveness of using a self-diagnostic model. This study's procedure was divided into two phases: the first phase was the development of the model by analyzing and synthesizing related principles and concepts as the basis for the development; the second phase focused on verifying its effectiveness by implementing the model into classrooms and evaluating the results with set criteria. The samples were randomly selected from Matayom 4 (grade 10) students of Sriboonyanon School. One classroom from 11 classrooms according to the students' item scores and assigned into experimental groups with 42 students. The experiment lasted for 18 hours. The instruments used in data collection were lesson plans focusing on the self-diagnostic process based on metacognition thinking principals about fraction problems, a mathematical problem solving test, a self-diagnostic ability test, a metacognition awareness questionnaire, and a self-regulated learning questionnaire. The One-Group Pretest-Posttest Design was used for the study. The data were statistically analyzed by using t-test for dependent samples and t-test one group.

The results showed that 1) the self-diagnostic model in the cognitive domain in problem solving skills in mathematics consisted of four components, including the principle of the model, the goal of the model, teaching and learning activities, and self-diagnostic test, and 2) the effectiveness of the self-diagnostic model revealed that students who had development in mathematical problem solving performance and self-diagnostic performance meant they had higher a posttest than pretest at the 0.1 level of significance, they had a metacognition awareness thinking process, a self-regulated learning higher posttest than pretest at the 0.1 level of

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significance, and they had a positive attitude towards the self-diagnostic model. In addition, teachers and students were accepting of the possibility of the practical application of these findings.

Keywords: Self-diagnostic model, Cognitive domain, Mathematics problem-solving

INTRODUCTION

From the O-NET results of Academic Year 2013-2015 in Matayom 3 (grade 9) and 6 (grade 12), the average score for mathematics was less than 50% (Sampan Panpluk, 2015). At the same time, the results of an international test for the research project "Trends in International Mathematics and Science Study" or TIMSS organized by the International Association for the Evaluation of Educational Achievement or IEA in the USA, in Matayom 2 (grade 8), indicated that Thailand had an average score for mathematics lower than the international average score of 500 and on the Programme for International Student Assessment or PISA which emphasizes the ability to analyze and comprehend complicated problems. The latest results indicated that there were exceeding numbers of Thai students who had knowledge of mathematics that was lower than the fundamental level should have for a minimum requirement, i.e. lower than the 2nd level, and the weakest point was mathematical thinking; that was to see the problems based on the circumstances in the context as the mathematical method (The Institute for the Promotion of Teaching Science and Technology, 2013). The significance of these results indicates that Thailand urgently requires an upgrade and the development of quality of mathematics education. Factors affecting the mathematical problem solving process, searching for knowledge in order to create

initiatives, and individual ideas for self-development and potential were collected from students, teachers, family members, and school. Findings of Polya (1957, 1985), The National Council of Teachers of Mathematics (NCTM,2000:52), Sudarat Monnimit (2002) and Jarung Khampong (1999) showed that problem solving is the intellectual ability to find out an unknown answer by applying a problem solving process to enhance new mathematical understanding. It is an individual talent that makes someone superior to others in mathematics. For this reason, Mathematics teaching should make it a priority to develop students' rational thinking ability simultaneously with comprehension in mathematics.

Elements influencing the mathematical problem solving process consist of ability to diagnose and use the self-cognitive process. Research results of Flavell (1979), Davidson et al. (1994); and Martinez (2006), illustrated that meta-cognition skills are very important to cognitive activities. It was related from the beginning steps of the learning process: communication, understanding of spoken language, understanding of reading and writing, memory, problem solving, and controlling. The results of Duangduen On-nuam (1988), Nongluck Samoephap (1994), Sudarat Monnimit (2002) and Kritcharat Wittayavet (2008) show that the mathematics learning diagnostic of students was very significant since a significant attribute of mathematics is that it is a serial subject. One content could not be learnt without having first mastered prior

fundamental matters. Thus, learning new topics without a clear understanding of the fundamentals led to a failure to learn mathematics. However, the research of Chote Petchchuen (2001: 10-11), Promphan Udomsin (1988: 93-94), Amornrat Soisangwan (2008) and other scholars concerning the diagnostic revealed that it was the integration of meta-cognition into teaching plans to resolve students' problems by the teacher or other people that made the key difference. Therefore, it was necessary to wait for the diagnostic results. Students could not immediately get the results since the teacher did not have time or was engaged in other commitments. It was a problem of ongoing learning in the higher levels, which are more difficult and complex.

The researcher was interested in enhancing the students' problem solving skills in mathematics and improving learning achievement by using a self-diagnostic model based on the metacognition process thinking principle.

Aims

To develop of a self-diagnostic model in the cognitive domain in problem solving skills in mathematics, and to study the effectiveness of using this self-diagnostic model.

Definitions in the Research

1. A self-diagnostic model in the cognitive domain in problem solving skills in mathematics refers to a method used to train learners to give information of misconceptions and solutions of their reflections on mathematical problem-solving by using self-

diagnostic forms based on the metacognition thinking process.

2. The metacognition thinking process refers to the hierarchy of thinking and a personally self-directed mind (Strategic Thinking). There are 5 steps in the metacognition thinking process: a. Understand the problem, b. Build an agent problem, c. Plan to solve the problem, d. Implement the plan to solve the problem, and e. Evaluate the problem solving.

3. Awareness of thoughts refers to one's thinking about thinking.

4. Self-directed learning refers to the learners' use of the metacognition process in planning, controlling themselves by inner motivation which includes a. Self-evaluation, b. Planning process and goal setting, c. Reminder note, d. Formatting and formatting change, e. Practice and memorization, f. Review of record, g. Reward success and punish failure, h. Information search, i. Environmental management, and j. Asking for help (Zimmerman; & Martinez-Pons. 1986: 614-628)

METHODS

This study procedure was divided into two phases which had the following details:

The first phase
"Develop of a self-diagnostic model in the cognitive domain in problem solving skills in mathematics" was the process of developing the model by analyzing and synthesizing principles and concepts as the basis for the development

The second phase

"Study the effectiveness of using a self-diagnostic model" focused on verifying its effectiveness by implementing the model in classrooms and evaluating the results with set criteria.

The first phase of Develop of a self-diagnostic model in the cognitive domain in problem solving skill in mathematics had 4 steps as part of the development as follows:

Step 1: Study problem-solving information and the idea related to a self-diagnostic model. The Ordinary national educational test (2015) reported that most of the students had a low ability in mathematical problem-solving. One of the good methods for enhancing their achievement is through improving self-learning skills.

Step 2: Develop a self-diagnostic model. I applied Bloom's (1971) concept of diagnosis, Polya's (1973) problem-solving skills in mathematics, Beyer's (1987: 192-197) and Davidson's; & Sternberg's (1994: 207-226) metacognition thinking process to design the conceptual framework of the self-diagnostic model which consisted of four components, namely, including the principle of the model, the goal of the model, teaching and learning activities, and a self-diagnostic test.

Step 3: Arrangement of the documents was planned by the arrangement provided by practical guidance, forms, and precedents. Analyzing mathematical misconceptions in Mathayom 4 (grade 10) from Suwimon S. (2010: 153-162) and choosing the content which was most regularly subject to misconceptions, namely, fractions, for this experiment. Three Lesson plans focusing on the self-diagnostic process based on metacognition thinking principals were

developed. The mathematical knowledge content for learning within each lesson plan consisted of 1. Adding and subtracting fraction word problems (5 hours), 2. Multiplying and dividing fraction word problems (5 hours), and 3. Fraction word problems (4 hours). The experiment lasted for 18 hours, divided into a pretest of 2 hours, learning activities for 14 hours, and a posttest 2 hours in length.

Step 4: Investigating a self-diagnostic model and documentation as detailed below.

1) Investigating the self-diagnostic model's appropriateness and index of consistency (IOC): the mean score was 4.9, the Standard Deviation (SD) was 0.17 and the Index of Consistency (IOC) was 0.89

2) Investigating the lesson plans' appropriateness and index of consistency (IOC): 1) the lesson plans' mean score was 4.2 with a SD of 0.49, the study notes mean score was 4.5 with a SD of 0.58, and the achievement testing mean score was 4.5 with a SD of 0.58.

Step 5: Try out the self-diagnostic model and documentation

Step 6: Improve the self-diagnostic model and documentation

The second phase "Study the effectiveness of using the self-diagnostic model"

Study samples

The samples were randomly selected from Matayom 4 (grade 10) students from the Sriboonyanon School. One classroom, from 11 classrooms, was chosen according to the students' item scores and assigned as the experimental group with 42 students in it.

Tools for collecting data were:

1. The mathematical problem solving test, included 20 subjective test items, was divided into subtests including adding fractions word problems, subtracting fractions word problems, multiplying fractions word problems, and dividing fractions word problems. The test was created by synthesizing content and concepts from Polya (1973: 5-40), Charles; & Lester (1982: 11-12), Rey; et al (1992: 313) and the Department of Academic Affairs (2001, 113-114) These same sources were used as guidelines for the criteria for the data capacity assessment which employed five point scoring rubrics. The author managed to analyze the quality of the subjective tests using both the B-index & Non 0-1 methods, which was applied for item analysis by Whitney & Sabers (1970). The item difficulty values (P) were 0.49-0.54 and the item discrimination (D) were 0.38-0.54. The internal consistency was tested using the Alpha-Coefficient method, giving a reliability value of 0.92.

2. The self-diagnostic ability test which consists of 30 items of subjective tests based on the metacognition thinking process in problem solving concepts proposed by Beyer (1987:192-196) and Davidson; &Sternberg (1994: 207-226). The criteria for the self-diagnostic of capacity assessment focused on the Department of Academic Affairs (2001, 113-114) using three point scoring rubrics. The author managed to analyze the content validity and diagnostic validity of the testing, with item-objective congruence: IOC uses the formula as below:

$$IOC = (“R)/N$$

The Analysis was divided into two parts as noted below:

Part A: Test-analyze the basic statistic values of the data with the SPSS for Windows analysis program which is used for analyzing fundamental data by means of descriptive statistics, i.e. mean, standard deviation, median, mode, highest and lowest values, and skewness and kurtosis. Analyze content and discriminant validity of testing, and measure of internal consistency of testing, with Cronbach's alpha method with the TAP analysis program.

Part B: Handbook- analyze the basic statistical values of data with the SPSS for Window analysis program Creating criteria by using five point scoring rubrics.

3. The metacognition awareness questionnaire. Creating the questionnaire originated by synthesizing the concepts and principles from Garner., & Alexander (1989: 143:158), O'neil., & Abedi (1996: 234-245), Swanson (1990 : 306-314), Paris., & Jacob (1984: 2083-2093) and Schraw., & Dennison (1994: 462-475). The criteria for the metacognition awareness assessment used a four level rating scale. The author managed to analyze the quality of the subjective tests with the analysis programs B-index & Non 0-1 methods. The discriminating power of the items were assessed with a t-distribution test , producing values for (t) of 2.88-7.91. The internal consistency was tested with the Alpha-Coefficient method, giving a reliability value of 0.88.

4. The self-regulated learning questionnaire was based on the metacognition thinking process. The criteria for the metacognition awareness assessment used a four level rating scale. Creating the questionnaire originated by synthesizing the

concepts and principles from Zimmerman., & Matinez-Pons (1986: 614:628), Pintrich, P. R., & de Groot, E. V.(1990: 33-40). The author managed to analyze the quality of subjective tests with the analysis program B-index & Non 0-1 methods. The discriminating power of items were compared with a t-distribution, with resulting values for (t) of 2.24-9.901. The internal consistency was tested with the Alpha-Coefficient method, resulting in a reliability value of 0.87.

Collecting data

Data collection for this study was a One-Group Pretest-Posttest Design (Saiyos, 1995: 249) as described in Table 1

Analysis of the data

This study had 4 steps in the data analysis process as follows:

Step 1: To compare the mathematical problem solving ability of students after being organized into learning groups focusing on the self-diagnostic process based on metacognition thinking concepts with the criterion, which t-tests one group as seen in table 2.

Step 2: To compare the self-diagnostic ability in mathematical problem solving of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts, and t-tested for dependent Samples as seen in table 3.

Table 1: Study plan

Group	Pretest	Experiment	Posttest
E	T_1	X	T_2

Symbol in the study plan
  E replace to   Experiment group
  X replace to   Self-diagnostic learning emphasized in metacognition thinking process
  T_1 replace to   Pretest
  T_2 replace to   Posttest

Table 2: Compare mathematical problem solving ability of students after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts with the criterion (70%)

	n	$\overline{X}$	K	s	μ_0(70%)	t
Posttest	42	90	68.10	11.09	63	2.98**

** passed the 70 percent at the .01 level of significance ($t_{(.01, 41)} = 2.421$)

Table 3: Compare self-diagnostic ability in mathematical problem solving of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts

E	n	$\overline{X}$	s	$?D$	$?D^2$	t
Pretest	42	19.74	4.11	2,035	101,103	40.19**
Posttest	42	68.10	11.09			

** at the .01 level of significance ($t_{(.01,41)} = 2.421$)

Step 3: To compare the metacognition awareness of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts, t-tested for dependent Samples as seen in table 4.

Step 4: To compare the self-regulated learning of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts, which was t-tested for dependent Samples as seen in table 5.

To compare the data in step 1, which was analyzed by the formula below:

$$t = \frac{\overline{X} - \mu_0}{\frac{s}{\sqrt{n}}} \quad ; \ df = n-1$$

To compare the data in stes 2 to step 4, which was analyzed by the formula below:

$$t = \frac{\sum D}{\sqrt{\frac{n\sum D^2 - (\sum D)^2}{n-1}}} \quad ; \ df = n-1$$

Table 4: compare the metacognition awareness of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts.

E	n	$\overline{X}$	s	$?D$	$?D^2$	t
Pretest	42	60.45	9.52	918	21,960	20.84**
Posttest	42	82.31	13.40			

** at the .01 level of significance ($t_{(.01,41)} = 2.421$)

Table 5: Compare the self-regulated learning of students before and after organized learning focusing on the self-diagnostic process based on metacognition thinking concepts.

E	n	$\overline{X}$	s	$?D$	$?D^2$	t
Pretest	42	51.29	10.02	743	13,759	29.60**
Posttest	42	68.98	20.91			

** at the .01 level of significance ($t_{(.01,41)} = 2.421$)

RESULTS

The results of this study showed that:

1) a self-diagnostic model in the cognitive domain in problem solving skills in mathematics consisted of four components, which included the principle of the model, the goal of the model, teaching and learning activities, and self-diagnostic tests as seen in figure 1.

2) the effectiveness of the self-diagnostic model revealed the student who had the development in mathematical problem solving performance, self-diagnostic performance meant they had higher posttest scores than pretest scores at the 0.1 level significant, they had a metacognition awareness thinking process, a self-regulated learning higher posttest than pretest at the 0.1 level significance, and the students had a positive attitude towards the self-diagnostic model. In addition, the teacher and students were accepting the possibility of the practical application of the model to real teaching and learning.
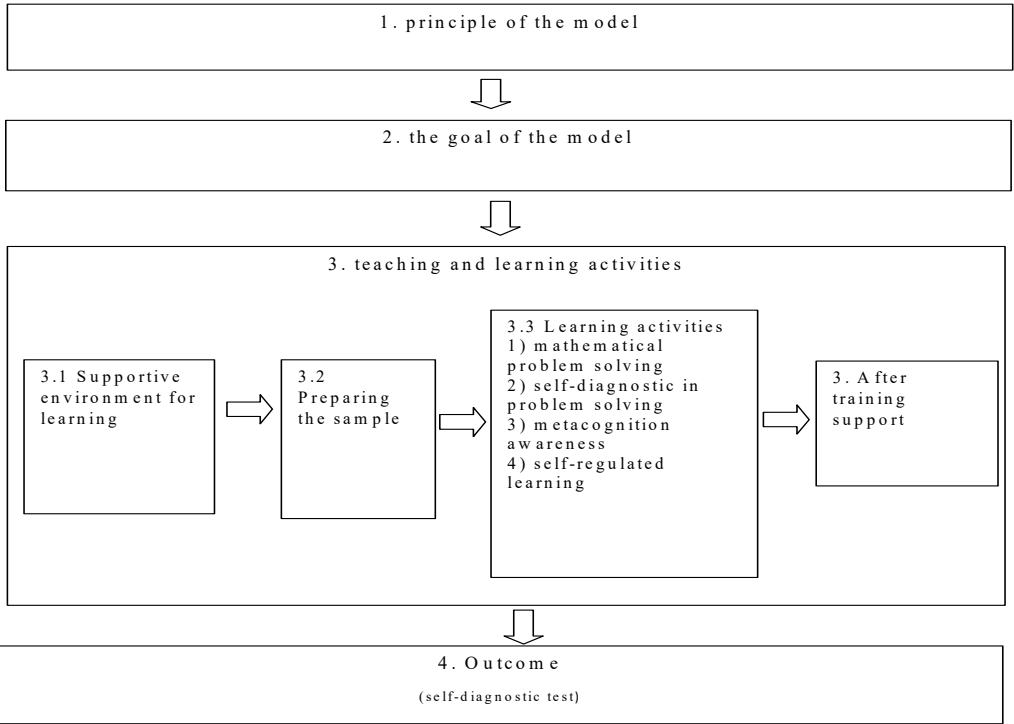

Figure 1: A self-diagnostic model in the cognitive domain of problem solving skills in Mathematics

2) the effectiveness of the self-diagnostic model revealed the student who had the development in mathematical problem solving performance, self-diagnostic performance meant they had higher posttest scores than pretest scores at the 0.1 level significant, they had a metacognition awareness thinking process, a self-regulated learning higher posttest than pretest at the 0.1 level significance, and the students had a positive attitude towards the self-diagnostic model. In addition, the teacher and students were accepting the possibility of the practical application of the model to real teaching and learning.

DISCUSSION

The development of a self-diagnostic model in the cognitive domain in problem solving skills in mathematics. A methodology in systematic reviews and meta-analyses of self-diagnostic was developed from the theories of Bloom (1971), Polya (1973), Tissana K. (2002), and Beyer (1987:192-196) and Davidson; &Sternberg (1994: 207-226), which analyzed of composition and content to support the synthesis of the purpose , the processes, and the outcomes of model. In addition, this model was investigated for internal consistency by a professional. Therefore, the the study looked at the use of a self-diagnostic model for achievement to enhance this purpose according to Bloom's learning model(1971). This study used a process involving 4 steps of mathematical problem solving for achievement.

The development of a self-diagnostic model was created using conceptual blending to increase the effectiveness of the diagnostic, including the principle of the model, the goal of the model, teaching and learning activities, and a self-diagnostic test. Tissana K. (2002), and Beyer (1987:192-196) and Davidson, &Sternberg (1994: 207-226) all argued that the thinking process consists of planning, monitoring, and assessment. In addition, Derry and Murphy (1986) presented actions or strategies for learning, including schema knowledge training, direct training, metamemory acquisition procedures and self-regulation to support the self-diagnostic model. It is essential that teachers should embed strategies for the utilization of learning in real situations and consider 5 keys factors when training and developing lessons, namely, the content's level of difficulty, the diagnostic skills of students, the knowledge level of the students, and the age of students.

Our results show that the effectiveness of the self-diagnostic model revealed the students who had improvement in mathematical problem solving performance passed the 70 percent at the .01 level of significance. According to Williams (2001), who studied problem-solving behavior, focusing on writing following the solving sequence is critical. The self-diagnostic performance meant they had higher posttest scores than pretest scores at the 0.1 level of significance. According to Tissana K. (2001) who studied metacognition, two vital processes for students are thinking about thinking and using self-thinking to control self-learning to focus on goal achievement. The metacognition awareness of the thinking process, resulted in the self-regulated learning higher posttest than pretest at the 0.1 level of significance, clearly demonstrating that the students had a positive attitude towards the self-diagnostic model. In addition, the teacher

and students were accepting the possibility of the practical applications of the model to real-world learning.

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