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The Implementation of Metacognitive Learning Approach in Developing Students' Mathematical Communication Ability

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Abstract

The skill to communicate thoughts effectively, including communicating mathematical ideas as its part, is required in facing future challenges. In fact, in general, students' mathematical communication skill is still low. Metacognitive learning encourages students to reflect on their learning process; individual reflection or interaction with teacher and classmates provides opportunities for students to communicate and explain their thoughts.

This research intends to study the application of metacognitive learning and its roles in students' mathematical communication ability. An experiment with pretest-posttest control group design was conducted on the 70 students of 10th grade of a senior high school at Sumedang, West Java, during the first semester. The students were divided into three categories of mathematical prior knowledge (MPK): high, middle, and low achiever. The instruments used were a mathematical communication test and a set of attitude questionnaires on metacognitive learning. The data were analyzed by using statistical test for equality of two means.

This study has found that the metacognitive learning approach is more effective to reach better result for middle achievers than conventional one. There is an interaction between learning approach and MPK towards the students' achievement and gain of mathematical communication ability.

Keywords: mathematical communication skills, metacognition, metacognitive learning approach.

A. Introduction

1. Background of the Research

One of the skills which is needed for facing the challenges in the future is communicating thoughts effectively. The changes in any work fields require team work, collaboration, and communication. Greenes and Schulman (1996) stated that a common need in all disciplines and in the workplace is the ability to communicate. All core subjects and all vocations require that people be able to: (a) express ideas by speaking, writing, demonstrating, and depicting them visually in different types of displays; (b) understand, interpret, and evaluate ideas that are presented orally, in writing, or in visual forms; (c) construct, interpret, and link various representations of ideas and relationships; (d) make observation and conjectures, formulate questions, and gather and evaluate information; and (e) produce and present persuasive arguments.

Sometimes we heard a student who learnt mathematics said like this, “I understand, but I can’t do it.” or “I’m sure that my answers are correct, but I feel confuse to give the reason.” From the words like that, it seems that the students had difficulties in expressing his/her idea or feeling hard to give the reason or explanation about the step to solve the problem which he/she made. For most of the students, explaining the process of thinking is a frightening task. Besides that, there are a lot of students who can finish doing mathematical problems in written way, but when they are required to clarify in spoken way, they seem that they cannot do anything or on the contrary, there are a lot of students who can comment in spoken way from a question or idea which is given, but too slow to express it in written form.

Sumarmo (2012) said that generally the students’ capability of mathematical communication is still low. The students are difficult to explain a situation to mathematical model or mathematical expression, they feel difficult to demonstrate algorithms of solving problems, to interpret solution in relation with the previous problems, and to find other alternative solution; the students hard to use the representation of graphics and tables as the ways to do test items and make representation of written texts. The phenomenon above shows the uncapability of the students to communicate mathematically. Because of that, doing exercise to communicate mathematically is needed.

Paying attention to the importance above, one of the roles that should be faced by the teachers of mathematics relates to the communicating problems. The importance of communication in teaching mathematics is shown by the fact that communication is one of the four standards of the National Council of Teachers of Mathematics (NCTM) for all levels of grades. The emphasis is to propose making the students have many opportunities to use language for communicating their mathematical ideas. The chances for explaining, thinking, and arguing ideas in spoken and written ways can stimulate to understand concepts and principles more deeply (NCTM, 2000). So that, speaking and writing about mathematics is an integral part in learning mathematics.

The same thing which was done by the National Council of Supervisors of Mathematics (NSCM) in 1989 (Reys et al., 1998) which has had twelve fields of essential mathematics registered by confirming again the importance of each field for the students in this twentieth century. One of the components which forwarded by NSCM is communicating mathematics ideas.

Recently, metacognition has got great attention in various kinds of mathematics education researches, and it is believed as one of the important parts of the learning process. Metacognition is based on the idea to test someone’s knowledge andthoughts, and also it relates to the activity to monitor and to control thinking process. Metacognition includes the knowledge of cognitive tasks, and the knowledge of one’s self.

Questioning is the source of important metacognitive. The students need to realize their strengths and weaknesses, and their procedures and strategies which they

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use to learn and do mathematics, more specially, solve problem. When doing mathematical activities, they ask question continually, “what do I do?”, “why do I do it?”, “how will it help me?” The activity to ask questions involves monitoring, controlling, and especially managing to understand by finding relevant information with the aims which are needed by the students to understand. Therefore, asking question is the main strategy in learning metacognitive. Creating questions and responding the answers which the students state is a way to stimulate thinking activity and talking about mathematics and the student involve in communication. The interaction like this gives the students chances to speak about their ideas, get feedback for their thinking, and listen to any other views. Teaching of metacognition encourages the students to reflect the process of their learning; and individual reflection with the others (whether teacher of friends) can give chances for them to communicate and explain their thought

2. Research Question

To get detail description, the problems are formulated through the following questions.

a) Do the students who get the metacognitivelearning indicate having mathematical communicationability better than the students who get conventional learning?
b) Do the students who get the metacognitivelearning indicate having of mathematical communicationability better than the students who get conventional learning seen from mathematical prior knowledge (high, middle, low)?
c) Is there any effect of interaction between teaching approaches and mathematical prior knowledge to the students’ mathematical communication ability?

B. Theoretical Framework

1. Mathematical Communication Ability

In 1989, national council of teachers of mathematics (NCTM) (NCTM, 2000) took a firm decision to the development of teaching mathematics. The change of the mathematics program is needed to prepare the students to live in societies which are changing fast at present. In each level of school, the standard of NCTM stresses on problems solving, mathematical communication, mathematical thinking, and mathematical connection. Communication is the important part of mathematics and the education of mathematics.

Furthermore, according to NCTM (2000), the instructional program of pre-kinder garden until the twelve-grade should make the students be able to:

a) arrange and combine their mathematical thinking through communication;
b) communicate the mathematical thinking coherently and clearly to friends, teachers, and others;
c) analyze and evaluate thinking and strategy to others;
d) use mathematical language to express mathematical ideas carefully

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Based on NCTM in 1989, national council of supervisors of mathematics (NSCM) (Reys et al., 1998) registered the twelve components of essential mathematics in 21st century. One of the components which was forwarded by NSCM is "communicating mathematical ideas" the recommendation in this field includes:

a) students should learn language and notation of mathematics. For example, they should understand the value of scientific place and notation;
b) students should learn to receive ideas of mathematics through listening, reading, and observing;
c) students should be able to express ideas of mathematics by speaking, writing, drawing pictures and graphics, and demonstrating with concrete models;
d) students should be able to discuss mathematics and put forward questions about mathematics.

In other words, one of the main points of the agreement between the recommendation of NSCM and NCTM is that communicating ideas of mathematics in many kinds of ways (spoken, written, symbolic language, daily language) is very important for the teaching process.

The researchers predict that there are a lot of learning processes in academic communication which happen in classrooms, and communication is very important for helping students to get critical language and thinking skill. When students participate in class discussion, they use language which is more accurate and relevant with the topics discussed, they become involved in the teaching, and then their qualities and quantities of their respond grow up.

Communication is a way of various concepts and clarifies understanding. Through communication, the students can explain and widen their horizon and understanding the mathematical relationships and arguments. The students also learn to involve in mathematical reasons and debates, learn how to criticize themselves and other ideas and find the efficient mathematical solution.

To make the students be active to involve in thinking and communicating requires the teachers use new approaches in teaching and class interaction. Teachers need to plan teaching process which can give time for students to practice their ideas and language, and to maintain the students be responsible for giving thoughts and ideas, to create dynamic class that supports every student participate and succeed.

Based on the statement above, it can be defined that mathematical communication capability is the capability to use mathematical language, and the capability to use mathematics to solve problems and to interpret it. The indicators the mathematical communication capability in this research includes:

a) stating a situation, pictures, diagrams, or real thing to languages, symbols, or mathematical models or vice versa;
b) constructing and explaining ideas, situation, and mathematical relationships or presenting it in visual form;

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c) stating events or daily problems as mathematical representation (in forms of pictures, graphics, and languages, symbols, or mathematical models.
d) Choosing and using mathematical representation for solving problem and interpret it.

2. Metacognition

The term of "metacognition"is from the word "cognition"which uses prefix "meta". In psychology dictionary (Corsini, 2002), cognition is meant as general term for the action to know and realize, such as: observing, understanding, reasoning, evaluating, planning, remembering, and imagining.Whereas"meta" is from Greek, the meaning in English is after, beyond, adjacent, self (Wikipedia, Free Encyclopedia, 2012). According to Larkin (2010),cognition is based on our capability to know or to think, and "meta" is based on the exceeding position or second order or higher. So that, the word "metacognition" describes rules which is higher than thinking, something that is reflective, exceeding general level to reflect thinking itself.

During 40 years, metacognition has been one of the main fields of research of cognitive development. The research of metacognitive activity was pioneered by John Flavell, who is considered as "father" in this field. Flavell was the first person who stated the term of metacognition in 1976 which its definition is as follows (Schoenfeld, 1992: 347):

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them,…. Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of those processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete (problem solving) goal or objective.

According the definition above, metacognition has two functions, those are, to monitor and to rule the thinking process. Metacognitionis described too byFlavell (Schwartz and Perfect, 2004; Serra and Metcalfe, 2009) as "the experiences and knowledge we have about our own cognitive processes", "cognition of cognition", "a critical analysis of thought", "knowledge and cognition about cognitive phenomena", or "thinking about thinking".

3. Teaching Mathematics by Metacognitive Approach

By studying the techniques are suggested by several experts, the following are registered teaching techniques which are going to be applied in this research that considered
to fulfill suggestions which are proposed.

a) Modeling

Teachers voice all thoughts and feelings which appear during doing a task (for example, solving problems, answering questions, doing experiments, reading notes from text books, etc.), in order that the students can follow the thinking process which are demonstrated. Thus the students know the effective ways to use knowledge and metacognitive capability. Modeling adds vocabulary which the students need to think and to speak about their thoughts themselves. Giving name for thinking process when the students use it is also important in order that the students know thinking ability (BlakeyandSpence, 1990; Gama, 2004).

b) Reflective Questions

Reflective questions are questions which are used by the teachers to drive the students to reflect the strategies which they use in doing academic tasks (for example: problems solving) and explaining their reasons to use those strategies. These questions will stimulate broad metacognitive monitoring (Gama, 2004). As examples, “Can you explain the way you use?”, “Can it be used for other problem?”, “Can you give the definition?”, “Is it suitable for our reason?”, “Have we found all possible answer?”

c) Metacognitive Scaffolding

Scaffoldingis an effective strategyto enterZPDinVygotsky’stheory, that is to bridgethe gap between what the students do by themselves and what they can do by other guidance. Inscaffolding, the teachers give the students opportunities to enlarge their capabilities and knowledge at that time. Teachers make the students’ interests participated, make the tasks easy to do, and motivate the students to reach the teaching goals, can see the suitable between the students’ efforts and their solution, control frustration and risks, and demonstrate action which is appropriate (KinardandKozulin, 2008). Metacognitive scaffoldingsupports the process which relates to the individual learning management and gives guidance for the way of thinking during learning. It may remind the students to reflect the goals or to support them to relate the use of the resources or tools which are given to finish tasks which are done. The goal of metacognitive scaffolding is to make the students self-dependent, be able to think independently, do not depend on their teachers (Hartman, in Gama, 2004).

d) Writing Metacognitive Journal

Writing journals is a teaching tool which is based on the idea that the students learn to write. The students use journals to write about topics which attract attention, to record the results of their observation, to imagine, to ask, and to relate the new information with things that they have known. The students who use journals actively engage in their own learning, and have opportunities to clarify and contemplate their thoughts. When they write in journal, they can record things like ideas and feelings, special words and expression which they hear, interesting things which happened to them (Saskatoon Public Schools, 2004).Specially, metacognitive journal show what the students learn and how they learn it.

e) In-pairs Discussion, Group Discussion, and All-Class Discussion

With their pairs or their groups, the students collaboratively discuss and do the tasks which are given in the form of students’ activity sheet, both the tasks for learning certain topics, and solving mathematical problems. During the students do the tasks, the teacher goes around the class and sometimes gives responses or reflective and metacognitive questions to the in-pairs or group discussion. Furthermore, several students present the results of the discussion to all class.

4. Research Hypotheses

Based on the research questions presented above, the hypotheses which were stated in this research are:

a) Students who get metacognitive learning shows better mathematical communication ability than the students who get conventional learning.
a) Students who get metacognitive learning shows better mathematical communication ability than the students who get conventional teaching, seen from the mathematical prior knowledge (MPK) (high, middle, and low).
b) There is an effect of interaction between the teaching approaches and the mathematical prior knowledge to the students' mathematical communication ability.

C. Method of Research

1. Subject of the Research

Subject of the research was the students of the tenth-grade of state senior high school at Sumedang district, West Java. As a sample, it took two classes, one was as experiment class (who got metacognitive teaching), and one was as control class (who got conventional teaching). The students of experiment class was 36 persons, they consisted of 15 male and 21 female, and the students of control class was 34 persons, they consisted of 12 male and 22 female.

The implementation and the data collection at school were held during one full semester, that was in old semester in 2013/2014 on July until December, 2013. The materialswhich were discussed during the research included (1) forms of exponents, roots, and logarithms, (2) quadratic functions and parabola, (3) quadratic equations and quadratic inequalities, and (4) system of linear equations.

2. Method and Design of the Research

The research was done is quasi-experiment, by using metacognitive teaching model which directly try to be applied in the teaching of mathematics to the students of a senior high school. Design of experiment which was used in this research is Nonequivalent [Pre-test and Post-test] Control-Group Design (Creswell, 2010: 242) as follows.

Group A O ——— X——— O

Group B O ————————— O

with:

X = metacognitive teaching
O = measurement by test and non-test

3. Instruments of the Research

a) Test of Mathematical Prior Knowledge (MPK)

Test of MPK is required to measure students'mathematical prior knowledge about the materials of mathematics which were studied before, when they were at Junior High Schools. The materials support in learning the core of discussion which was discussed during this research. Type of MPK test items was short complete, all of it was 20 items. The right answer was given score 1, and the wrong answers was given score 0. The ideal maximum score was 20. The category of MPK was as follows.

Table 1
Category of MPK

Group	Mastery Level	Scores
High	75% – 100%	15 – 20
Middle	55% –74%	11 – 14
Low	< 55%	0 – 10

b) Test of Mathematical Communication Ability

Test of mathematical communication ability is arranged based on the indicators mathematical communication ability and the teaching goals on the core of discussion which was discussed. The test consisted of six test items. Guide for giving scores to the answers included in Table 2, which was adapted from the QUASAR Cognitive Assessment Instrument (QCAI) General Holistic Scoring Rubric (Lane in Elliot and Kenney: 1996).

Table 2
The Mathematical Communication Ability Scoring Rubric

Sore	Response
0	No response; or if answer given, words do not reflect the problem, or drawings completely misrepresent the problem situation.
1	Has some satisfactory elements but may fail to complete or may omit significant parts of the problem; may include a diagram that incorrectly represents the problem situation, unclear and difficult to interpret. Explanation or description may be missing or difficult to follow.
2	Response is in the proper direction, but the explanation or description may be somewhat ambiguous or unclear; may include a diagram that is flawed or unclear.
3	Provides a fairly complete response with reasonably clear explanations or descriptions; may include a nearly complete, appropriate diagram, may contain some minor gaps.
4	Provides a complete response with a clear, unambiguous explanation or description; may include an appropriate and complete diagram.

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A part from that based on the criteria, the giving scores also paid attention to the characteristics of items. The items which required explanation/description which was long enough, or required connection of several mathematical concepts and principles, or required involute and long computation, it was given weight 1. Whereas the items which required a little mathematical concepts or principles, or required doing simple computation, it was given weight ½. And also, the test items which were the continuation from the test items given before, in this case, a part of the solution process on the given test items before had been done, it was given weight ½.

The instruments of MPK and mathematical communication ability carry through the consultation step and tryout to fulfill the requirementof qualified validity, reliability, difficulty index, and discriminatory power.

4. Techniques of Data Analysis

The data which were processed was the scores of pre-test, post-test, and n-gain. In each aspect, if the beginning ability is the same, the difference of average scores of post-test and the improvement will be tested. On the other hand, if the beginning ability is not the same, the difference of scores of the average improvement will only be tested. The data processing used the help of *Microsoft Excel 2007*and*SPSS 20 for Windows*with significance level 0.05.

D. Research Findings

1. Mathematical Prior Knowledge (MPK)

The students who are involved in this research were 36 persons of experiment class and 34 persons of control class. The grouping of the students was based on the results of the MPK test was in the following.

Table 3
The Number of the Research Sample

Level MPK	Experiment Class	Control Class	Total Number
High	8	10	18
Mediocre	14	11	25
Low	14	13	27
Total Number	36	34	70

The data of MPK was used as the moderator variable betweenindependent variable and dependent variable.

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2. Mathematical Communication Ability

The summary of the data of mathematical communication ability test results and the result statistical examined was presented in Table 4.

Table 4
Summary of the Mathematical Communication Ability Tests and the Results of Tests of Different Means

Group	Class	n	Pre Test			Post Test			n-gain		
			Average	Std. Dev.	Test of Diff. Means	Average	Std. Dev.	Test of Diff. Means	Average	Std. Dev.	Test of Diff. Means
All	Experiment	36	0.29	0.59	Not different	22.47	7.95	Not different	0.59	0.21	Not different
	Control	34	0.43	0.48		21.41	7.29		0.56	0.19	
High	Experiment	8	0.50	0.71	Not different	31.63	2.79	Not different	0.83	0.07	Not different
	Control	10	0.60	0.57		30.80	2.30		0.81	0.06	
Mediocre	Experiment	14	0.39	0.71	Not different	25.61	4.40	Different	0.67	0.11	Different
	Control	11	0.45	0.47		20.36	3.83		0.53	0.10	
Low	Experiment	14	0.07	0.27	Not different	14.11	3.02	Not different	0.37	0.08	Not different
	Control	13	0.27	0.39		15.08	3.45		0.39	0.09	

Ideal score = 38

3. Effect of Interaction betweenLearning Approaches and MPKto the Mathematical Communication Ability

The result of*Tests of Between-Subjects Effects*showed that there is an interaction between learning approaches and MPK to the achievement ofmathematical communication ability(0,008 < 0,05), and there is an interaction between learning approaches and MPK to the improvement ofmathematical communication ability(0,008 < 0,05). It is shown in the picture bellow.

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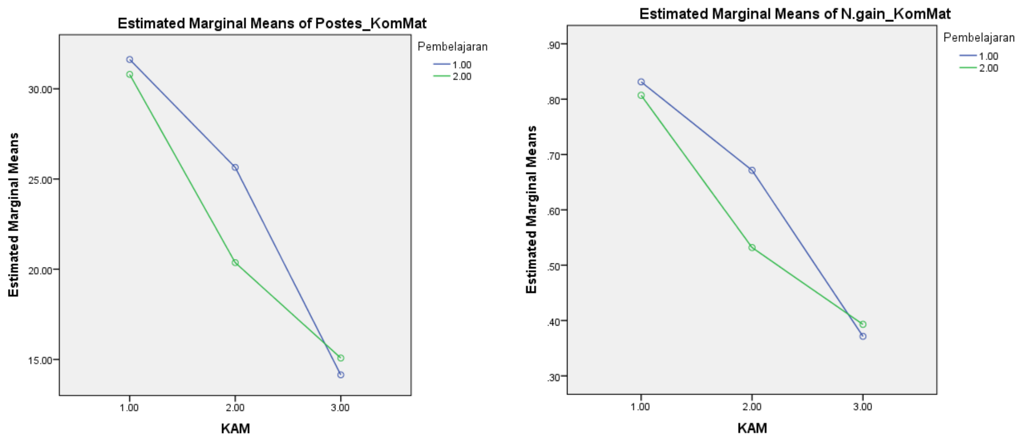

Picture 1
Effect of Interaction between Learning Approaches and MPK to the Mathematical Communication Ability

E. Conclusion

Based on the results of the data process and analysis, the conclusions have been obtained as follows.

a) As a whole, there has not been difference in mathematical communication ability between the students who had got metacognitive learning and those who had got conventional learning.
b) Seen from mathematical prior knowledge, the students of middle group who had got metacognitive learning had shown better mathematical communication ability than those who had got conventional learning.
c) There has been influence of interaction between learning approach and mathematical prior knowledge on the students' mathematical communication ability.

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