ANALYSIS OF ENHANCEMENT OF MATHEMATICAL COMMUNICATION COMPETENCY UPON STUDENTS OF MATHEMATICS EDUCATION STUDY PROGRAM THROUGH METACOGNITIVE LEARNING

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Abstract

Various studies have pointed out communication in mathematics to be one of the necessary competencies within learning mathematics. Student teachers are expected to possess such competency in order to communicate learning materials in efficient and effective manner which is supposed to create easiness for students to learn. A particular learning approach which is allegedly to enhance mathematical communication competency is the metacognitive learning approach. This research was conducted by undertaking mixed method with sequential explanatory strategy. Design of study is pretest-posttest control group design (Creswell, 2009). The population are Mathematics Education's student who attends the course of mathematical statistics. The population is students of mathematical statistics course in Kupang Province of East Nusa Tenggara, Indonesia with sample 65 students. The sampling technique is purposive sampling. Two separate classes of a Mathematical Statistics course of at the University in Kupang were randomly selected to be distinguished as an experimental class and a control class. The instrument of this study is test of mathematical communication competence. Results show that there is enhancement in mathematical communication competency upon students of the group which were learning through the metacognitive learning approach (MLA) and the conventional learning approach (CLA). Learning outcomes and enhancement in mathematical communication competency of the MLA group was found to be higher than those of the CLA group. For both groups, the lowest average enhancement was upon the indicator of expressing certain situation or mathematical relationship into mathematical model (graph, figures, and mathematical expressions). Highest average enhancement was found upon the indicator of outlining significance upon given situation or problem, which occurred within both groups.

Keywords: Mathematical Communication, Metacognitive Learning

CHAPTER I: INTRODUCTION

Communication becomes an inseparable factor in the process of learning. The process of transferring information of knowledge and experiences occurs between teachers and students, students and students, and between students and learning materials, which entails forms of communications.

A thought is an internal representation which is ought to be expressed externally by means of communication. Mathematical ideas which have been derived and expressed through mathematical languages in figures, graphs, texts, and mathematical models, are designed to be comprehensible to the audience. This utterance is parallel to those of Jamison (Kabael, 2012) who argues that mathematical language is composed by logical structure and rhetoric which is comprehensible towards all parties, and is presented based on definition formats, proof, and theory. Conveying mathematical ideas clearly and accurately presents irrefutable significance.

Since early age, children are encouraged to comprehend and express mathematical facts, thoughts and ideas they possess. This allows children to be accustomed to expressing mathematical ideas in accurate and correct manners in such way to be comprehensible to the audience. Children should be trained to express mathematical ideas in mathematical sentences in order to simplify the problems and solutions. This confirms to NCTM (2000) which underlines that communication in mathematics is an utmost significance and therefore should be exposed to children at an early age.

Besides the importance to be comprehensible to the audience, communication is beneficial to evaluate correctness of thinking. Through communication, correctness of mathematical ideas by students can be evaluated by their peers as well as their teachers. By this medium, students will be encouraged to realize upon their mistakes in mathematical thinking and therefore will be encouraged to undertake correction. This statement confirms to that of NCTM (2000) which utters that communication enables mathematical thinking to be observable and encourages students to reflect upon self-mathematical thinking as well as mathematical thinking of others.

The importance of communication is underlined by the National Council of Teachers of Mathematics (NCTM, 2000, 29), which suggests that in learning mathematics, there are four competencies which are ought to be attained by student. There are problem solving, reasoning, communication and representation.

In accordance to NCTM, within the Decree of Indonesian Minister of Education Number 22 Year 2006 regarding standard contents of mathematics, The 2013 Curriculum set out in Decree of Indonesian Minister of Education Number 64 Year 2013 regarding standard contents of the 2013 curriculum, and Decree of Indonesian Minister of Education Number 65 regarding the 2013 curriculum process standards, it is stated that aims of mathematics learning are upon the following: (1) solving problems which comprise ability to comprehend to problems, design mathematical model, solve upon the model, and interpret the solution; (2) communicating ideas with symbols, tables, diagrams, and other mediums in order to clarify certain situations or problems; and (3) possessing attitudes in respecting practicality of mathematics in daily life, which comprises of possessing curiosity, concerns and interests towards learning mathematics, alongside being tenacious and confident in solving mathematical problems.

Recalling significance of mathematical communication competency, it is therefore required particular mathematical learning strategy which has potential to increase mathematical communication competency. One of the strategies which have potential to increase mathematical communication competency is the metacognitive strategy.

The metacognitive strategy entails a sequential process which is used to control the cognitive activities and to ensure that cognitive aims are realized. This process comprise of planning and monitoring cognitive activities and evaluating outcomes of these cognitive activities. Activities of planning are among deciding on aims and analyzing tasks in assisting activation of relevant knowledge in order to ease up organizing and comprehending learning materials. Further, assisting on how students utilize their cognitive abilities, monitoring process of thinking and applying strategies in rearranging the thinking process in order to strive for efficiency and effectiveness in solving problems, are main aspects of the metacognitive approach.

The illustration above shows that mathematical communication competency is an utmost significance ought to be possessed by students in learning mathematics. Therefore, it is required a study which analyzes upon mathematical communication competency of students, especially those being prepared to be teachers of mathematics. These students righteously possess mathematical communication competency in order to convey information in effective and efficient manner which eases students in learning.

Derived from the introductory above, problem of this study is formulated as: (1) Are there differences upon outcomes of mathematical communication competency between the group of students of metacognitive learning approach and the group of students of the conventional learning approach? (2) Are there differences upon enhancement of mathematical communication competency between the group of students of metacognitive learning approach and the group of students of the conventional learning approach? (3) Which indicator of mathematical communication competency of students resulted as to be the highest? (4) Which indicator of mathematical communication competency of students resulted as to be the lowest?

Aim of this research is to identify: (1) differences upon outcomes of mathematical communication competency between the group of students of metacognitive learning approach and the group of students of the conventional learning approach; (2) differences upon enhancement of mathematical communication competency between the group of students of metacognitive learning approach and the group of students of the conventional learning approach; (3) Highest and lowest indicator of student mathematical communication competency.

CHAPTER II: LITERATURE REVIEW

2.1 Mathematical Communication Competency

Communicating upon and through mathematics is part of learning to become a problem solver of mathematics and learning to think mathematically. Communication can be developed to encourage students to use their own words in expressing their own ideas, and to record their thoughts in various mediums such as through words, symbols, diagrams, and models.

Dan (2013) identifies mathematical communication competency as the ability to comprehend to and express mathematical facts, thoughts, and ideas. Previously, Sumarmo (Koswara, Sumarmo, Kusumah, 2012) analyzed upon various experts' suggestions thus concluding that characteristics of mathematical communication competency comprises of: (a) constructing real objects, figures and diagrams into mathematical ideas; (b) explaining mathematical ideas, situations, and relationships by oral and written expressions, or by means of real objects, pictures, figures, and algebra; (c) explaining daily events in mathematical symbol languages; (d) listening, discussing, and writing upon mathematics, comprehensive reading upon mathematical presentations; (e) explaining and drafting questions upon learnt mathematical materials.

The explanations on mathematical communication competency above comprise of two main points which are representing mathematical ideas correctly in form of figures, graphs, and algebra, and expressing mathematical ideas by oral or written expression which would be easy to comprehend to by its audience. Representation is a means of structuring certain situations thus creating a more meaningful expression. The audience are bound to comprehend to a particular concept if it were top be communicated in comprehensible and appealing fashion.

NCTM (2000) suggests that indicators of mathematical communication competency in mathematics learning comprises of: (1) Ability to express mathematical ideas through oral and written expressions, and to visually demonstrate and depict them; (2) Ability to comprehend to, interpret, and evaluate mathematical ideas correctly in oral and in other visual terms; (3) Ability to utilize mathematical terms, notations and its structures in order to present ideas, picture relationships and situational models.

In detail, Sumarmo (2003) identifies mathematical communication indicators in mathematics learning as: (1) constructing real objects, figures and diagrams into mathematical ideas; (2) explaining mathematical ideas, situations, and relationships by oral and written expressions, or by means of real objects, pictures, figures, and algebra; (3) explaining daily events in mathematical symbol languages; (4) listening, discussing, and writing upon mathematics, (4) reading written mathematical presentation and drafting relevant questions; (5) constructing conjectures, composing arguments, crafting definitions and generalizations; (6) explaining and drafting questions regarding the learned mathematics.

The indicators of mathematical communication competency described above are the indicators of mathematical communication competency which generally used for middle school learning. Recalling that this research is conducted upon university students, alongside the circumstances of literature shortages, therefore indicators of mathematical communication competency throughout this study is formulated as: (1) expressing particular situation or mathematical relations into a mathematical model form (graph, figure, and mathematical expression); (2) constructing particular problem or case out of a certain mathematical model (graph, figure, and mathematical expression); (3) describing meaning of a particular given situation or problem.

2.2 Metacognitive Strategy

AeU (2011) suggests several metacognitive strategies in which can be applied in the teaching-learning process, as: Self-Questioning, KWL (Know, What, Learn), PQ4R (Preview, Question, Read, Reflect, Recite and Review), and IDEAL (Identify, Define, Explore, Act, Look). These strategies are described in the proceedings:

a. Self-Questioning Strategy

Self-Questioning is a strategy which aims to enhance awareness of students upon the thinking process within themselves. Tan (AeU, 2011) argues that the Self-Questioning strategy encourages students to monitor their cognitive process along evaluation of their thinking process. This enables students to undertake self-corrections and to develop new understandings.

b. KWL (Know, What, Learn) Strategy

Dixon-Krauss (AeU, 2011) defines KWL as a strategy that allows students to identify what they already know, what they want to learn, and what is to be learned. Stages within this strategy are: (i) Students discuss upon their current knowledge; (ii) Students discuss upon what they need to learn construct a list of information on their current knowledge; (iii) Teacher motivates students to identify the materials in which is to be learned. This particular stage may begin with reflecting on what the students want to learn and based on what they already know.

c. PQ4R Strategy

PQ4R strategy comprises the stages of preview, question, read, reflect, recite and review (AeU, 2011). This particular strategy assists students to process substantial information within a limited time. This allows students to direct their thoughts to given tasks prior to complete study. Descriptions of sequences of the PQ4R strategy are as follows (AeU, 2011): (1) Preview: material survey in order to obtain general ideas, main topics, and subtopics. This stage entails observing title and figures to identify on what is to be learned. (2) Question: construct questions in regards to learning materials. These questions (what, how, why) are constructed based on aims and goals of the particular learning. (3) Read: Study on learning materials in regards to given tasks, and answering the self-constructed questions from the previous stage. (4) Reflect: reflect on learning materials already been read and attempt to enact significance. (5) Recite: practice remembering and expressing gained ideas, asking and answering. (6) Review: review on learning materials while focusing on the self-constructed questions, reconstruct questions and reread learning materials if unsure on answers, thereafter construct a summary.

d. IDEAL (*Identify, Define, Explore, Act, Look*) Strategy

IDEAL is a particular strategy of the metacognitive approach which promotes effectiveness and efficiency in thinking and problem solving (AeU, 2011). Teachers who are concerned with facilitating thinking and problem solving in effective manners are bound to convey metacognitive competencies upon students. Effective problem solving should begin with identifying difficulty potentials which is then to be followed by problem identification. The next sequence is exploration. Students are to take act on their own solution. Generally students who possess sufficient competency will plan on their thinking process, go through reflections and be open-minded in searching for solutions. Finally, subsequent to finding solution, students record on what is required to obtain optimal solutions.

The metacognitive strategies described above generally emphasize on conditioning students to be able to trace their thinking process through self-constructed questions in regards to monitoring and evaluation. These metacognitive strategies have several aspects in common such as the stages of planning, monitoring, and reflecting mathematical ideas expressed in their work, followed by a review process. These strategies promote on encouraging students to prepare learning materials required for the whole learning process aligned with learning aims and goals. Students are directed to monitor their own ideas and bring significance to the solutions they retrieve.

CHAPTER III: RESEARCH METHOD

This research undertakes a pretest-posttest control group design (Creswell, 2009). Group of experiment are treated with a metacognitive learning approach, whilst goup of control are treated with conventional learning approach.

Population of this research accounts for all students of the even semester of academic year 2014/2015 who are undertaking a course in Mathematical Statistics in Mathematics Education Study Program of Teachers Training and Education Faculty in a particular University in Kupang City. Research sample was filtered as 65 students which were selected through a purposive sampling technique. Initial competency of both groups was homogenous. Research instrument is test on mathematical communication competency.

Quantitative data were analyzed through descriptive and inferential approach in regards to outcomes and enhancements of mathematical communication competency. Hypothesis testing undertook parametric and non-parametric statistical analysis.

CHAPTER IV: RESULT AND DISCUSSION

4.1 Outcome of Mathematical Communication Competency

Hypothesis of difference tests upon mathematical communication competency outcomes are as follows:

H_0 : There is no difference in outcomes of mathematical communication competency amongst groups of different learning approaches.

H_1 : There is difference in outcomes of student mathematical communication competency amongst groups of different learning approaches.

Results of significance test employing a t-test is presented in Table 4.1.

Table 4.1
Difference Test of Mathematical Communication Competency Outcomes between 2 Test Groups

Approach	**n**	**Avg.**	**Avg. Dif.**	***t***	**df**	***Sig.***	**Declaration**
MLA	33	24.15	7.28	4.50	63	.000	H_0 rejected
CLA	32	16.88					

Based on the t-test results presented in Table 4.1, value of probability (sig.) is lower than $\alpha = .05$, and therefore H_0 is rejected. This signifies that the group of students being taught through the metacognitive learning approach yield higher outcomes in terms of mathematical communication competency than those students of the conventional learning approach group.

4.2 Mathematical Communication Competency Enhancement

Difference test upon mathematical communication competency enhancement between two groups undertakes the following hypothesis:

H_0 : There is no difference enhancement upon mathematical communication competency between two groups of different learning approaches.

H_1 : There is difference enhancement upon mathematical communication competency between two groups of different learning approaches.

Results of significance test employing a t-test is presented in Table 4.2.

Table 4.2
Difference Test of Mathematical Communication Competency Enhancement Between 2 Test Groups

Approach	n	Avg.	Avg. Dif.	*t*	dof	*Sig.*	Declaration
MLA	33	0.71	0.22	4.83	63	0.000	H_0 rejected
CLA	32	0.58					

As depicted in Table 4.2, the t-test results identify a rejection towards H_0 as the probability value (sig.) is lower than α (.05). By this, it is concluded that the group of students of the metacognitive learning approach yield higher average enhancement of mathematical communication competency than those students of the conventional learning approach.

Enhancement in mathematical communication competency for both test groups generally lies on the average scale, however enhancement for the metacognitive learning group were higher than the conventional learning group. Within the metacognitive approach, students are conditioned to explore and study upon various learning sources, identify constraints, self-construct questions, answer questions and utter ideas. These particular activities trigger students to explore their insights which would ease the students in delivering upon ideas in regards to working on given tasks. Through a comprehensive study upon various learning materials, students are deemed to be more enhanced in comprehending to materials and therefore will be more confident. Identifying and comprehending to process of work completion from various sources enriches student knowledge and in turn boosts their confidence to communicate.

The metacognitive approach encourages students to construct questions, answer the questions and deliver ideas in discussions. These activities trigger students to employ their current knowledge in expressing a situation. The mere activity of delivering ideas within a discussion eases students in completing on given tasks. Browsing for solutions upon various sources allows students to make significance on what is being learned and to express ideas comprehensible to the audience.

Interview results suggest several external factors that affect the students mathematical communication competency. These factors are amongst heavy workload of tasks given by teachers, shortages of access to learning sources, fatigue, relationships between students and between students and teachers, and academic atmosphere. Heavy workload of tasks pinned on students by teachers leads to student fatigue. Deadline of task submission is deemed too short which heaps pressure on the students. This particular condition would indeed result in physique and mental fatigue. A tired physique would convey a lapse in concentration in learning activities within the mathematical statistics subject. A decline in concentration would result in low comprehension of students towards learning concepts thus leads to low competency of mathematical communication.

Within the metacognitive learning, students are guided to self-identify learning concepts. This method pushes students to study from various references of learning resources. Difficulty in obtaining references is one of the constraints experienced by the students. The school library does not provide sufficient sources and literatures. Access to references from the internet is unlikely to be experienced by the students due to insufficient internet connection and frequent power outages, adding to costly internet accesses. In this case, students are bound to constraints in access to a wider source of alternative learning materials.

Learning atmosphere in the classroom is found to be one of the factors affecting student learning activities. A quiet and serene atmosphere is expected to support the learning activities. Mutual interactions in assisting and respecting each other would convey positive contributions towards enhancing mathematical communication competency. A high intensity of interactions would be a significant contribution by students in creating a better learning atmosphere.

Table 4.3 depicts average enhancement of mathematical communication competency based on indicators.

Table 4.3
Average Enhancement of MCC Indicators

Mathematical Communication Competency Indicators	**SMI**		**LEARNING APPROACH**					
			MLA			**CLA**		
			Pretest	**Post-test**	**N-Gain**	**Pretest**	**Post-test**	**N-Gain**
Expressing mathematical situation or relationship into forms of mathematical models (graph, figure, and mathematical expressions) **(1)**	12	$\bar{X}$	0.61	7.15	0.58	0.31	4.13	0.33
		S	1.20	3.96	0.35	0.69	2.84	0.24
Constructing problem or cases based on mathematical models (graph, figure, and mathematical expressions) **(2)**	12	$\bar{X}$	0.97	8.36	0.66	0.97	4.81	0.36
		S	1.36	2.84	0.26	1.03	2.98	0.25
Outlining significance upon given situation or problem **(3)**	12	$\bar{X}$	0.64	8.64	0.71	1.31	7.94	0.62
		S	1.08	2.12	0.18	1.09	2.27	0.22
TOTAL		$\bar{X}$	0.74	8.05	0.65	0.86	5.63	0.43
		S	0.73	2.29	0.20	0.55	2.04	0.17

Note: $\bar{X}$: average, S: Standar Deviation

As depicted in Table 4.3, there are enhancement of mathematical communication competency for all indicators at MLA and CLA groups. Average enhancement of the expressing mathematical situation or relationship into forms of mathematical models (graph, figure, and mathematical expressions) of the MLA group is found higher than those of the CLA group. The highest enhancement occurred for the outlining significance upon given situation or problem indicator, whereas the lowest average increase occurred for the expressing mathematical situation or relationship into forms of mathematical models (graph, figure, and mathematical expressions) indicator.

Table 4.3 furthermore informs that average enhancement of the outlining significance upon given situation or problem indicator is found to be higher than total average increase of all indicators. Further, standard deviation of this indicator is found lower compared to total standard deviation. Hence, it can be concluded that the metacognitive learning enhances student competency in outlining significance upon given situation or problem. In account for other indicators, average increase does not exceed total average increase of all indicators, whereas standard deviation does not fall short compared to standard deviation of all indicators. This concludes that metacognitive learning does not enhance student competency in expressing mathematical situation or relationship into forms of mathematical models, and competency in constructing problem or cases based on mathematical models (graph, figure, and mathematical expressions).

In regards to comparing pretest scores between MLA and CLA groups, average score upon the three indicators do not show considerable differences, whereas posttest scores comparison show relatively major differences. Upon indicators (1) and (2), enhancement of mathematical communication competency (denoted by N-gain) of the MLA group decently differs from those of the CLA group, whilst for indicator (3), enhancements show similarity.

Interview results point out that students experience difficulties in working on tasks related to the aspect of expressing mathematical situation or relationship into forms of mathematical models (graph, figure, and mathematical expressions). This is taken on account of proper grammar constraints in expressing ideas. Students are found inferior due to anxiety of using improper grammar in encountering with the researcher. This leads to vary cautious using of sentences by the students.

CHAPTER V: CONCLUSION AND SUGGESTION

5.1 Conclusion

Referring to research results and discussions in the previous section, several conclusions are drawn as follows:

1. There are differences in outcomes and enhancements of student's mathematical communication competency in general.
2. The enhancements of mathematical communication competency for both groups lie on an average scale, however, enhancements found upon the MLA group was higher than those of the CLA group.
3. The highest enhancement occurred for the outlining significance upon given situation or problem indicator.
4. Lowest enhancement occurred for the expressing mathematical situation or relationship into forms of mathematical models (graph, figure, and mathematical expressions) indicator.

5.2 Suggestion

Derived from the conclusions, several suggestions are uttered as follows:

1. Metacognitive learning approach in Mathematical Statistics subject enhances student competency in mathematical communication, and therefore the metacognitive approach should be considered as an alternative learning approach for students.
2. Interview results pointed out practices of the metacognitive approach in regards to task workload and time allocation as considerable pressure, and therefore it is suggested upon consideration regarding workload and time allocated for students upon completing the tasks, as well as improving access to alternative learning sources.
3. Research results identify the metacognitive learning approach to enhance mathematical communication competency in general, and therefore it is suggested upon further study related to metacognitive learning approach towards other mathematical competencies.

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