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IMPROVING STUDENTS' MATHEMATICAL COMMUNICATION ABILITIES THROUGH THE PROBLEM BASED LEARNING LEARNING MODEL

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Abstract
Mathematical Communication Skills (MCS) is not only a tool to convey mathematical ideas, but also an important part of the mathematics learning process. In fact, students' MCS is still very low and needs further action, so an alternative is needed that can develop better students' MCS. The purpose of this study was to determine the increase in students' MCS after the Problem Based Learning (PBL) learning model was applied. The research method used was a mixed method with concurrent triangulation design. Samples were taken using random sampling techniques from the total population of all students in class X MAN 1 Aceh Barat and students in class X MIA-6 were selected as research samples. Data were collected through tests and interviews which were then analyzed using normalized N-Gain and qualitatively. The results of the study found that the overall increase in students' MCS was in the medium and low categories, however, the increase in all indicators of students' MCS was quite good, where (1) students were able to communicate mathematical thinking coherently and clearly, (2) were able to use mathematical language to express mathematical ideas correctly, but some students made mistakes when making mathematical models, (3) were able to organize and consolidate mathematical thinking through communication, although some students were still confused about the steps to solve it, and (4) were able to analyze and evaluate mathematical thinking and strategies used by others. However, some students were only able to analyze and were less able to evaluate mathematical thinking and strategies used by others. Overall, students have had a good MCS.
Keywords: mathematical communication skills, problem based learning, indicators

INTRODUCTION

Mathematics is a branch of science that studies structures, patterns, relationships, quantities, spaces, and changes that use symbols and logical rules to construct valid arguments and solve problems, so mathematics needs to be taught to all students from elementary school to college so that they can think logically, analytically, systematically, critically, creatively, and have the ability to work together (Yani, et al, 2022). Therefore, mathematics has an important role in life to solve problems in everyday life.

In addition, mathematics also greatly supports the development and application of other fields of science such as physics, chemistry, economics, astronomy, and other sciences. This means that without mathematics, several branches of science cannot function properly. Because the general purpose of learning mathematics is to help develop students' abilities to be able to act critically, logically, systematically, and straightforwardly in facing a world that is increasingly developing rapidly (Hafriani, et al, 2025).

In the curriculum in Indonesia, the objectives of mathematics have five parts known as the mathematical power process standards of mathematics learning according to the NCTM, namely problem solving, reasoning and proof, communication, connections and representation (Effendi, 2012). Mathematical Communication Skills (MCS) are one of the mathematical skills that must be possessed by students. Umar (Purnama & Afriansyah, 2016) stated that MCS are very necessary to be developed in mathematics learning, this is because students are able to organize their mathematical thinking well both verbally and in writing which is greatly influenced by their MCS.

Communication skills are the ability of students to communicate certain information not only with words but also using symbols, images, graphs, and others. While MCS are the ability of students to convey mathematical information/ideas both verbally and in writing, and also through symbols, images, graphs and others. The importance of MCS is possessed by students because it is a tool to convey various ideas clearly, precisely, and concisely, as well as a means of interaction between teachers and students (Nuraeni, 2018).

However, Ruseffendi (Ansari, 2015) stated that the largest part of mathematics learned by students in schools is not obtained through mathematical exploration, but through notification. In reality, teachers in schools when teaching directly explain the material and provide examples of problems along with solutions to students, so that students only watch the teacher solve the problem, then students are given exercises that are in accordance with the examples. In other words, teachers only give routine problems to students.

Furthermore, Buhaerah (Sari & Rahadi, 2014) stated that among the factors causing low MCS of students in mathematics lessons is caused by teachers who focus too much on mechanical and procedural matters, which causes learning to be centered on the teacher and the mathematics material is delivered informatively and students are trained to solve many problems without training their MCS. A'yun, Ibrahim, and Yani (2021) also stated that low MCS are certainly also caused by many factors. One of the causal factors is that students are generally less trained in solving problems that are contextual in substance, requiring reasoning, argumentation and creativity in solving them. As a result, students' MCS do not develop as they should. In fact, the 2013 curriculum really emphasizes the importance of creativity and communication which are formulated in terms of attitude, knowledge and skills competencies (Yeni, 2014).

The low MCS of students can cause students to have difficulties and problems with their mathematics learning achievements. This can be seen from the results of initial observations at MAN 1 Aceh Barat, where students' ability to work on story problems had difficulty in translating the meaning of the questions so that they were confused in working on them. Students had difficulty interpreting information from the questions and had difficulty understanding mathematical symbols. During the initial observation, the researcher asked the mathematics subject teacher to choose three students who would be given a MCS test, after the next test they were interviewed and the results showed that the two students did not understand the information from the questions and the students had difficulty understanding the symbols contained in the questions.

The results of the TIMSS (Trends in International Mathematics and Science Study) data analysis also showed that students were less enthusiastic, even students left questions with long information and tended to be interested only in routine questions that were directly related to formulas and were weak in application questions that contained a story even though the questions were simple (Suwarsono, 2013). This happens because the creativity and MCS of students are still not well developed, where students are accustomed to solving questions that do not require complex mathematical analysis and communication skills. The results of research conducted by Zulfah and Rianti (2018) also show that students' MCS are still in the weak category in making mathematical models.

To overcome the above problems, the Problem Based Learning (PBL) learning model is assumed to be an alternative solution in solving these problems, especially in efforts to improve students' MCS. Arends (Yani & Karina, 2020) stated that the PBL learning model is a learning model that directs students to solve authentic problems with the intention of compiling their own knowledge, developing inquiries, and stimulating critical and creative thinking processes, acting as adults, and producing work.

Based on the definition above, the PBL learning model provides opportunities and chances in learning activities that can help the process of developing and improving students' MCS. The results of Rosa and Pujiati's (2016) research also concluded that there was a significant influence of the PBL learning model on critical thinking skills and creative thinking skills together. The purpose of this study was to determine the improvement of students' MCS through the implementation of the PBL model at MAN 1 Aceh Barat.

METHOD

The research method used in this study is a mixed method with concurrent triangulation design. The purpose of using this method and design is to collect and analyze quantitative and qualitative data simultaneously with the same weight, then compare or combine them to gain a deeper understanding of a phenomenon being studied.

Population is all data that concerns us in a scope and time that we determine. All students of class X MAN 1 Aceh Barat are the population taken in this study. Furthermore, the researcher took samples using random sampling techniques, where each member of the population has an equal chance of being selected as a sample. In other words, all single members of the population have a non-zero chance. Students of class X MIA-6 totaling 33 students were selected as samples in this study.

In this study, data were collected through tests (pretest-posttest) and interviews. The test questions in question are questions that have been arranged according to the indicators of MCS in the form of essays. The test was conducted twice, namely pretest and posttest. The MCS test instrument was developed from the material of the Three Variable Linear Equation System (TVLES) with a score for each MCS question having a maximum weight of 16 which is divided into 4 components of ability.

The data collected through the test was analyzed using the N-Gain formula (Irwan, 2009) as follows:

$$\text{N-gain } = \frac{(posttest\ score - pretest\ score)}{(ideal\ max\ score - pretest\ score)}$$

Table 1. N-Gain Score Criteria

Gain Score	Interpretation
0,70<g≤1,00	High
0.30<g≤0,70	Medium
g≤0,30	Low

Furthermore, the data collected through interview techniques was analyzed qualitatively with the following stages: (1) data reduction, (2) data presentation, and (3) drawing conclusions (Yani, et al, 2016).

RESULTS AND DISCUSSION

The results of the pretest and posttest data analysis on students' MCS using N-gain showed that after participating in learning with the PBL learning model, 10 students had a medium N-gain level and 23 students had a low N-gain level. However, there was 1 student in the medium category approaching high and 7 students in the low category approaching medium. The N-gain results showed that students' MCS after the PBL learning model was applied had an average low N-gain level. This means that the increase in students' MCS after the PBL learning model was applied was not very significant, where the increase in the high category was 0%, the increase in the medium category was 30.3%, and the increase in the low category was 69.7%.

The development or improvement of students' MCS based on the results of the pretest and posttest for each indicator of students' MCS is described as follows.

Indicator 1: *Communicate mathematical thinking coherently (logically arranged) and clearly to friends, teachers and others.*

In the first indicator, the initial MCS of students can be seen from the scores obtained by students, the number of students who obtained a score of 0 was 27 students and those who obtained a score of 3 were 6 students, however after implementing learning through the PBL learning model for the first indicator there were no more students who obtained a score of 0. There were 7 students who obtained a score of 1, 6 students who obtained a score of 2, 12 students who obtained a score of 3, and 8 students who obtained a score of 4. Thus it can be said that the indicator of communicating mathematical thinking coherently (arranged logically) and clearly to friends, teachers and others has experienced good development or improvement.

Indicator 2: *Using mathematical language to express mathematical ideas correctly.*

In the second indicator, the initial MCS of students can be seen from the scores obtained by students, where 32 students received a score of 0 and 1 student received a score of 1, however, after implementing learning through the PBL learning model for the second indicator, students who received a score of 0 had decreased to 13 students, those who received a score of 1 increased to 13 students, 6 students received a score of 2, and 1 student received a score of 4. This shows that the indicator of using mathematical language to express mathematical ideas correctly has developed or improved well.

Indicator 3: *Organizing and consolidating mathematical thinking through communication.*

In the third indicator, the initial MCS of students can be seen from the scores obtained by students, where students who obtained a score of 0 were 25 students and those who obtained a score of 1 were 1 student, 4 students obtained a score of 2, and 3 students obtained a score of 4. However, after implementing learning through the PBL learning model for the third indicator, students who obtained a score of 0 were 31 students, and those who obtained a score of 2 were 2 students. This shows that the indicator of organizing and consolidating mathematical thinking through communication did not experience better development or improvement.

Indicator 4: *Analyze and evaluate mathematical thinking and strategies used by others.*

In the fourth indicator, students' initial MCS can be seen from the scores obtained by students, the number of students who obtained a score of 0 was 15 students and those who obtained a score of 1 were 14 students, 2 students obtained a score of 2, 1 student obtained a score of 3, and 1 student obtained a score of 4. However, after implementing learning through the PBL model for the fourth indicator, 17 students obtained a score of 0 and 16 students obtained a score of 1. This shows that for the indicator of analyzing and evaluating mathematical thinking and the strategies used by others, there has been no better development or improvement.

The recapitulation of the development or improvement of students' MCS is as shown in the following table.

Table 2. Improvement of Students' MCS

Indicator MCS	Pretest	Posttest
Communicate mathematical thinking coherently (logically organized) and clearly to peers, teachers and others.	The number of students who got a score of 0 was 27 students and those who got a score of 3 were 6 students. There were no students who got scores of 1, 2, and 4.	There are no more students who get a score of 0. There are 7 students who get a score of 1, 6 students who get a score of 2, 12 students who get a score of 3, and 8 students who get a score of 4.
Using mathematical language to express mathematical ideas correctly.	Many students received a score of 0 (32 students) and 1 student received a score of 1, while no students received scores of 2, 3, and 4.	The number of students who received a score of 0 has decreased to 13 students, the number of students who received a score of 1 has increased to 13 students, 6 students received a score of 2, and 1 student received a score of 4.
Organizing and consolidating mathematical thinking through communication.	The number of students who got a score of 0 was 25 students and those who got a score of 1 were 1 student, 4 students got a score of 2 and 3 students got a score of 4.	There were 31 students who received a score of 0, 2 students who received a score of 2, and no students received scores of 1, 3, and 4.
Analyze and evaluate mathematical thinking and strategies used by others.	There are 15 students who get a score of 0 and 14 students who get a score of 1, 2 students get a score of 2, 1 student gets a score of 3, and 1 student gets a score of 4.	There were 17 students who got a score of 0 and 16 students who got a score of 1, and no students got a score of 2, 3, and 4.

Meanwhile, the improvement in students' MCS is based on the N-gain value based on the medium and low category groups as presented in the following table.

Table 3. Increase in MCS Based on N-Gain Value

Indicator MCS	Medium		Low	
	Pretest	Posttest	Pretest	Posttest
Communicate mathematical thinking coherently (logically	Students are not yet able to present information obtained from	Students are able to present all the information contained in the problem.	Students are able to present information obtained from the problem, but there	Students are able to present information obtained from the problems

organized) and clearly to peers, teachers and others.	problems		is still one piece of information that is not mentioned.	given.
Using mathematical language to express mathematical ideas correctly.	Students do not provide answers	Students are able to use appropriate and correct symbol notation to express mathematical ideas.	Students do not provide answers	Students are able to use symbolic notation to express mathematical ideas, but only make examples
Organizing and consolidating mathematical thinking through communication.	Students demonstrate an appropriate understanding of the concept, inappropriate strategies, and incomplete answers.	Students demonstrate an appropriate understanding of the concept, inappropriate strategies, and incomplete answers	Students do not demonstrate proper understanding of concepts and strategies	Students do not demonstrate proper understanding of concepts and strategies
Analyze and evaluate mathematical thinking and strategies used by others.	Students have analyzed other people's answers, but have not provided appropriate reasons.	Students have analyzed other people's answers, but have not provided appropriate reasons.	Students do not analyze other people's answers and do not provide appropriate reasons.	Students do not analyze other people's answers and do not provide appropriate reasons.

From the results of the N-Gain data analysis on students' MCS, it is in the medium and low category. In general, students' MCS in solving contextual story problems are still very low, this can be seen from the results of the analysis of students' pretest answers. Students' ability to express information is still very low, where the low ability of students to express mathematical ideas or change story problems into mathematical models causes students to have difficulty in solving the problems given correctly. However, after implementing learning through the PBL model, students' ability to express information has developed or increased, as well as students' ability to use mathematical language to express mathematical ideas correctly has been able to develop well or increased.

However, there are still some students who have difficulty in making mathematical models. Based on the results of the pretest and posttest, the indicators of organizing and consolidating mathematical thinking through communication and the indicators of analyzing and evaluating mathematical thinking and strategies used by others did not experience better improvement. This is because students are not yet accustomed to learning with the PBL model, so students need to adapt to a different learning atmosphere than usual.

There is an increase in students' MCS after the implementation of the PBL learning model, although the increase is in the medium and low categories, it cannot be separated from the advantages of the PBL learning model itself. Abidin (2014) stated that the PBL learning model has several advantages, namely: (a) able to develop students' learning motivation, (b) encourage students to optimize their metacognitive abilities; (c) learning becomes meaningful which can encourage students to have high self-confidence and be able to learn independently; and (d) encourage students to be able to think at a high level. These four advantages are always optimized in every implementation of learning, especially in the aspect of developing students' learning motivation. Motivation for students to be enthusiastic and have a desire to learn is always developed at the beginning of learning activities after apperception activities, one of which is by linking the material on the three-variable linear equation system that will be studied with the context of students' real lives and the benefits of the material for students in a sustainable manner.

The success of the implementation of the PBL learning model in this study is also relevant to the research results of Yani and Karina (2020) which concluded that (1) the implementation of the PBL learning model on the material of flat-sided spatial figures in class VIII MTsS Lhong Raya Banda Aceh can improve student learning outcomes; (2) classically has achieved completion of 90.1%; and (3) student responses in the very positive category towards the implementation of the PBL learning model.

In the application of the PBL learning model, several things must also be considered, so that its application can be maximized and effective and obtain significant results as expected, such as (a) Selection of problems that are relevant to the context of students' lives and challenging; (b) The role of the teacher is as a facilitator who guides students in thinking about solving problems; (c) Formation of effective discussion groups, meaning heterogeneous and balanced to utilize various abilities and perspectives; (d) Good planning and time management; and (e) Flexibility and adaptability, meaning that teachers must be ready to face unexpected situations when students solve problems.

In the research of Yani and Karina (2020) it is also recommended that at the stage of orientation of students to problems, it is better to use problems that are very close to the students' environment and the problems given are relevant to the students' level of thinking or cognition, so that the impact on students' motivation to make hypotheses, investigate, and solve the problems given will be higher and the time for implementing the PBL learning model will be more efficient. Halimah, Haikal, and Ramadani (2024) also provide recommendations from the results of their research after implementing the

PBL learning model, namely that in order for the implementation of the PBL model in schools to be more mature, adequate support is needed to increase its effectiveness, especially in terms of improving learning outcomes. Furthermore, teachers must have good classroom management in implementing the PBL learning model and adjustments are needed in the assessment method, which should not only focus on mastery of the material, but also on critical thinking skills and student problem solving in accordance with the objectives of the PBL model.

CONCLUSION

The results of the findings and data analysis can be concluded that overall the ability of students is in the medium and low categories towards improving MCS, however, the achievement for each indicator is quite good, where students are able to communicate mathematical thinking coherently and clearly to their friends and teachers. Students are also able to use mathematical language to express mathematical ideas correctly, but some students make mistakes when making mathematical models. Students are able to organize and consolidate mathematical thinking through communication, although some students are still confused about the steps to solve it. Students are able to analyze and evaluate mathematical thinking and strategies used by others. However, some students are only able to analyze and are less able to evaluate mathematical thinking and strategies used by others. Overall, students have good MCS.

Based on the findings in this study, it can be suggested that the implementation of the PBL model requires readiness from teachers and students, where teachers must be able to understand the PBL model syntax and its characteristics well and completely. Furthermore, students must also have the readiness to learn differently than usual and are required to think critically and creatively. An important thing that needs to be considered is time management in the implementation of the PBL model, because it greatly determines the completeness and effectiveness of learning as expected, so that every problem presented by the teacher must consider the time and cognitive level of students.

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