Students problem-solving abilities using the problem-based learning model with a metacognitive approach

Simon M Panjaitan\textsuperscript{1,*} and A JB Hutauruk \textsuperscript{1}

\textsuperscript{1}Universitas HKBP Nommensen, Jalan Sutomo No.4A. Medan, Indonesia

\*Email: simon.panjaitan@yahoo.co.id

Abstract. This article is about research on the study of improving students' problem-solving abilities in the learning process using the Problem Based Learning learning model with the Metacognitive approach. This article also contains a study of the interaction between the learning model and the students' mathematical prior knowledge towards problem-solving abilities, and the study of student behavior in improving mathematical problem-solving skills. The research uses quantitative research methods with research subjects students in the experimental class and the control class. The research instrument consisted of tests of mathematical problem-solving abilities, observation sheets, and interview guidelines. Research findings include (1) the learning model used does not have a significant difference in mathematical problem-solving skills, both overall and based on prior mathematical knowledge, (2) the learning model used does not have a significant effect on improving mathematical problem-solving abilities, both overall and based on mathematical prior experience, and (3) there is no interaction between learning models and mathematical prior knowledge to improve mathematical problem solving abilities.

1. Introduction

Mastering mathematical skills are very important to be achieved to be able to play a role in competing and achieving progress [1,2]. Although in the learning process of mathematics there will be various difficulties in learning activities, sometimes the difficulties are deliberately made to train and familiarize students to get used to logical, systematic and reflective thinking activities, and problem-solving activities that are diligent, thorough and earnest. Mathematical skills are often known as mathematical proficiency [1] with one of its basic skills is mathematical problem-solving ability [3].

Mastering mathematical skills through problem-solving skills are one of the goals of mathematics learning [4]. By learning mathematics, students are expected to have basic mathematical abilities [5] which include mathematical understanding, mathematical connections, mathematical flexibility, mathematical reasoning, mathematical problem solving, mathematical communication and having an attitude of appreciating the usefulness of mathematics in life. Problem-solving skills can be developed through non-routine questions and through contextual problems that require unfamiliar solutions [6]. The development of non-routine problem-solving strategies depends on understanding the concepts involved in the problem and the relationship between the concepts.

Committee on the Undergraduate Program in Mathematics [7] expresses cognitive recommendations for students who are studying mathematics is to build and develop the ability of problem-solving approaches. Students must be able to think analytically and critically in formulating, solving, and interpreting problem solutions. This is in line with the practical mathematical standard by the Common Core State Standards for Mathematics (CCSSM) [7] that in order to develop problem-solving abilities, students should have mathematical skills in terms of understanding problems and persevering in solving
them; abstract reasoning; construct appropriate arguments and critical reasoning; mathematical model; strategies for using the right tools; students' mathematical skills to communicate appropriately to others; find and use patterns; and find and express order in repeated reasoning.

From the description above, it appears that problem-solving ability is a mathematical ability that is very important to improve in mathematics learning. But the ability to solve problems is still an obstacle in the process of learning mathematics. Some research on students' mathematical abilities [8, 9, 10, 11, 12] found several difficulties experienced by students, among others: unable to explain the concept into a simpler form; understanding of the concept to start solving problems is not satisfying; unable to find the relationship between concepts, definitions and related formulas; arrange conclusions according to the facts given; lack of ability to simplify questions in mathematical form; cannot associate or explain the meaning of the mathematical symbols used; and unable to compile a problem / case based on the model given.

The main factors that influence students' thinking abilities and mathematical problem-solving abilities are teaching methods, educational media, and the nuances of education [13]. Learning that is still centered on the teacher (teacher-centered) causes students to lack self-awareness, lack critical thinking, less creative, less independent, and less communicative [14, 15]. Learning that supports mathematical problem-solving skills is learning that allows each learner to do mathematics (doing the math) and student-centered. Problem-Based Learning (PBL) learning with a metacognitive approach is one of the learning models that are expected to support the development of mathematical problem-solving abilities [16, 17, 18].

Problem-Based Learning (PBL) with a metacognitive approach organizes the learning process in problem-solving activities, allowing students to convey ideas, arguments, solutions and be able to interact fully during the learning process [19, 20]. The learning process with PBL begins with the provision of problems in contextual situations related to daily life (real-life situation), generally in the form of a story problem (word-problem), where the settlement procedure is ill-structured, and guidance is given to develop and create contra- argument [21].

A metacognitive approach is a learning approach that emphasizes sequential stages that are used to control cognitive activities and ensure that cognitive goals have been achieved [9]. In a metacognitive approach, students consciously design, monitor, and monitor their learning processes, and can foster confidence and independence in learning [22]. The metacognitive approach emphasizes the development of students' awareness of their ability to understand concepts, understand problems, develop new knowledge relationships with old ones, settlement strategies, reflect processes and solutions that teach how to control thinking and thinking about thinking processes, especially in understanding problems, considering resolution strategies problem, reflecting on the methods and solutions that have been done [23, 24, 25].

In-depth research on the treatment of learning involves the analysis of student mathematical prior knowledge (MPK). MPK is a way of grouping students based on the initial abilities possessed by each student before being given treatment to see more clearly the mathematical skills of groups of students who are most affected after being given a learning treatment.

2. Method
This research is a quasi-experimental study with the subject of the study consisting of students divided into two classes which are differentiated based on the learning applied to each class, namely the experimental class uses PBL models with metacognitive approaches, and the control class uses conventional learning. The research instrument consisted of tests of prior mathematical knowledge (MPK), mathematical problem-solving ability tests, and observation sheets. The prior mathematical knowledge (MPK) test is given to students to know students' initial mathematical abilities before the learning process takes place and then group them into three groups of mathematical skills, namely the upper, middle and lower groups. Test the problem-solving ability based on indicators of problem-solving abilities. The observation sheet is used as a guide to observing all activities of students and lecturers during the learning process. Analysis to test the research hypothesis using the help of SPSS software, including the t-test, n-gain test, Mann-Whitney test, and two-way ANAVA test.
3. Result and Discussion
The MPK score was collected and analyzed at the beginning of this study. These initial mathematical ability data are grouped according to the first, high, medium, and low ability categories. Based on the grouping of MPK categories in the study sample, the distribution of research samples is arranged in the following table 1.

| MPK     | Control Class | Experiment Class | Sum |
|---------|---------------|------------------|-----|
| High    | 6             | 8                | 14  |
| Medium  | 29            | 26               | 55  |
| Low     | 8             | 7                | 15  |
| Sum     | 43            | 41               | 84  |

Furthermore, a pretest was conducted to determine the ability of students before being given learning and post-test to assess the ability of students after being given education.

| MPK     | Experiment   | Control        |
|---------|--------------|----------------|
|         | Pretes       | Pretes         |
| H       | 62.500       | 87.500         | 69.167 | 89.167 |
| n       | 8            | 8              | 6      | 6      |
| M       | 39.231       | 75.192         | 45.172 | 75.345 |
| n       | 26           | 29             | 29     | 29     |
| L       | 13.571       | 62.143         | 20.625 | 66.875 |
| n       | 7            | 7              | 8      | 8      |
| Overall | 39.390       | 75.366         | 43.953 | 75.698 |

From table 2, overall, the differences in the average pretest score are very small between the experimental class and the control class, with an average difference of 4.563. Likewise, the difference in the average posttest score is very small between the experimental class and the control class, with an average difference of 0.342. In other words, overall, there is almost no difference in mathematical problem-solving abilities in the experimental class and control class both before and after being given the PBLM model treatment.

For the High MPK category, it was seen that the average score of students' experimental mathematical problem-solving ability before learning was smaller than the average control class score. After being given treatment, it appears that the mathematical problem-solving ability of students in the control class is higher than the experimental class, but with a fairly small difference of 1.667. In other words, in the High MPK category, there is a fairly small difference between the mathematical problem-solving abilities of the experimental class and the control class after being given treatment during learning.

The average score of the mathematical problem-solving ability of experimental class students in the Medium MPK category before learning is smaller than the average control class score. After learning is done, it appears that the mathematical problem-solving abilities of students in the control class are higher than the experimental class, but with very little difference. The average score of the two classes is only different from 0.153. In other words, in the Medium MPK category, there is almost no difference in
mathematical problem-solving abilities between the experimental class and the control class after being given treatment during learning.

The average score of students’ mathematical problem-solving ability in the experimental class Low MPK before learning is smaller than the average control class score. After learning is done, it appears that the mathematical problem-solving ability of students in the control class is higher than the experimental class with a difference in the average score of 4.732. In other words, in the Low MPK category, there are differences in mathematical problem-solving abilities between the experimental class and the control class after being given treatment during learning. Then statistical analysis with $\alpha = 5\%$ is applied to analyze the significance of these differences.

**Table 3. Variance Test of Problem Solving Abilities Pretest**

| Problem Solving Abilities | T     | Df     | p-value (2-tailed) |
|---------------------------|-------|--------|--------------------|
| Equal variances assumed   | -1.262| 82     | .210               |
| Equal variances not assumed| -1.259| 79.894 | .212               |

Based on Table 3 above, it can be seen that the significance of $0.21 > \alpha$ so that it can be said that the average initial ability to solve mathematical problems of students who obtain PBLM learning is equal to the average initial mathematical problem-solving abilities of students who get conventional education.

**Table 4. Variance Test of Problem Solving Abilities Posttest**

| Statistic       | Posttest |        |
|-----------------|----------|--------|
| Mann-Whitney U  | 786.500  |        |
| Wilcoxon W      | 1647.500 |        |
| Z               | -.862    |        |
| Asymp. Sig. (2-tailed) | .388     |        |

Based on Table 4 above it can be seen that the significance of $0.388 > \alpha$ so that it can be said that the average final ability to solve mathematical problems of students who obtain PBLM learning is equal to the average initial ability to solve mathematical problems of students who get conventional learning. From these findings, it can be seen that based on the MPK category, the mathematical problem-solving ability in the experimental class was not higher than the control class after being given the learning treatment. In other words, it can be seen that the PBLM learning model is no better than the conventional learning model in achieving students’ mathematical problem-solving abilities. PBLM models are not able to provide differences in mathematical problem-solving abilities when compared to conventional learning.

Furthermore, from Table 4, there is an increase in the scores of mathematical problem-solving abilities for the experimental and control classes from the pretest and posttest scores. This increase shows the influence caused by the treatment of PBLM learning models on mathematical problem-solving abilities. To find out the increase in mathematical problem-solving abilities of students who obtained PBLM learning with students who obtained conventional learning, a normalized gain analysis was conducted in both classes.

From Table 5, there is an increase in the scores of mathematical problem-solving abilities for the experimental and control classes from the pretest and posttest scores. This increase shows the influence caused by the treatment of PBLM learning models on mathematical problem-solving abilities. To find out the increase in mathematical problem-solving abilities of students who obtained PBLM learning with students who obtained conventional learning, a normalized gain analysis was conducted in both classes.
Table 5. N-Gain Descriptive Statistics

| Class     | MPK        | Mean of N-Gain | N   | Std. Deviation |
|-----------|------------|----------------|-----|----------------|
| Experiment| High MPK   | .6652          | 8   | .07561         |
|           | Medium MPK | .5936          | 26  | .15628         |
|           | Low MPK    | .5593          | 7   | .14038         |
|           | Total      | .6017          | 41  | .14277         |
| Control   | High MPK   | .6278          | 6   | .11386         |
|           | Medium MPK | .5507          | 29  | .26709         |
|           | Low MPK    | .5837          | 8   | .24145         |
|           | Total      | .5676          | 43  | .24410         |
| Total     | High MPK   | .6491          | 14  | .09183         |
|           | Medium MPK | .5710          | 55  | .22083         |
|           | Low MPK    | .5723          | 15  | .19430         |
|           | Total      | .5842          | 84  | .20067         |

Based on table 5, can be described as the mathematical problem-solving abilities of students as follows:
a. The average n-gain mathematical problem-solving ability of students who obtained PBLM was higher than students who obtained conventional learning.
b. For students in the High MPK category, the average n-gain mathematical problem-solving ability of students who obtain PBLM is higher compared to students who obtain conventional learning.
c. For students in the Medium MPK category, the average n-gain of mathematical problem-solving abilities of students who obtain PBLM is higher than students who obtain PK.
d. For the Low MPK category students, the average n-gain mathematical problem-solving ability of students who obtained PBLM was lower compared to students who received conventional learning.
e. Average n-gain mathematical problem-solving abilities of the High MPK category students is higher than the medium and low MPK category students.

To find out the significance of the findings above, a two-way ANOVA test was applied with α = 5%. Summary of calculation results can be seen in table 6.

Table 6. N-Gain Variance Analysis

| Source         | Type III Sum of Squares | df | Mean Square | F     | Sig.  |
|----------------|-------------------------|----|-------------|-------|-------|
| Corrected Model| .101                    | 5  | .020        | .508  | .770  |
| Intercept      | 20.006                  | 1  | 20.006      | 500.873 | .000 |
| Kelas          | .002                    | 1  | .002        | .043  | .837  |
| KAM            | .081                    | 2  | .041        | 1.018 | .366  |
| Kelas * KAM    | .008                    | 2  | .004        | .098  | .907  |
| Error          | 3.116                   | 78 | .040        |       |       |
| Total          | 31.193                  | 84 |             |       |       |
| Corrected Total| 3.217                   | 83 |             |       |       |

Based on table 6, the findings can be described as follows:
a. From the value of sig. 0.837> α obtained that the increase and achievement of mathematical problem-solving abilities of students who obtain PBLM learning are not significantly higher than the increase and achievement of mathematical problem-solving abilities of students who obtain conventional learning as a whole.
b. From the sig value in the amount of 0.366> α, it was found that there was no significant difference in the improvement of students’ mathematical problem-solving abilities between those who obtained
PBLM learning compared to the increase in students' mathematical problem-solving abilities who obtained conventional learning based on student MPK.

c. Interaction between learning methods and students' initial mathematical ability categories with sig values. $0.907 > \alpha$ shows that there is no interaction effect between the learning used and MPK to improve students' mathematical problem-solving abilities.

The research findings were used in answering the urgency of this study. Descriptively, it appears that the very small difference in the average score cannot be shown to be the significance of the difference in treatment of PBLM models in the learning process. The very small difference in the average score change also indicates that the influence caused by the PBLM learning model on mathematical problem-solving abilities is also very small when compared with the influence caused by conventional learning models.

The difference in the average score for each MPK category also did not show a significant difference. The PBLM learning model in each MPK category provides a very small change in the average score. It also indicates that the influence caused by the PBLM learning model on mathematical problem-solving abilities is also very small when compared with the influence caused by conventional learning models.

Descriptively, it can be seen that there are differences in the number of scores on the calculated posttest and gain results. But from the results of hypothesis testing regarding the significance of the influence of the learning model shows that the difference is meaningless. The difference in scores obtained by both PBLM classes and conventional classes did not show a significant effect on mathematical problem-solving abilities. In other words, neither PBLM models nor conventional models can show an influence on students' mathematical problem-solving abilities.

The results obtained statistically as if contradicted the study of the theory, which tends to suspect that the PBLM learning model will have a significant effect on students' mathematical abilities. In theory, the combination of giving problems as the initial basis for learning PBLM learning models supported by the metacognitive learning approach will provide a real difference when compared to conventional learning models. But this turned out to be a contradiction with the results of statistical analysis which showed that there was no significant difference between the average score of students' problem-solving abilities obtained using the PBLM learning model compared with the average score using conventional models. Thus statistically, there is no influence that can be given by the PBLM model on problem-solving abilities.

According to researchers, the cause of differences in theory with statistical analysis is because there is no noticeable difference in the daily learning process carried out. In a conventional learning model, questions are given to students to work on, and then the resolution process is guided directly. In the PBL learning process, problems are also given to students as the basis of the learning process, but by adding a metacognitive approach in each step of PBL learning, the learning process seems to be like the teacher gives direct instructions or assistance to students in solving their problems. As a result, the learning process tends to look similar so that students are captured in the same way as conventional learning models. So when given a test to see the difference in problem-solving abilities, the results obtained were also not too different and even tended to be the same.

4. Conclusion

Conclusions obtained from this study include (1) the learning model used does not have a significant difference in mathematical problem-solving abilities, both overall and based on prior mathematical knowledge, (2) the learning model used does not have a significant effect on improving mathematical problem-solving abilities, both overall and based on prior accurate experience, and (3) there is no interaction between learning models and mathematical prior knowledge to improve mathematical problem solving abilities.

References

[1] National Research Council 2001 Adding it up: helping children learning mathematics In J.Kilpatrick, J.Swafford & B.Findell (eds) (Washington DC: National Academy Press)
[2] Hendrayana A 2015 The Effect Of Rmt Learning On Conceptual Understanding, Strategic Competencies, And Mathematical Cognitive Load Of Smp Boarding School Students (Bandung: Doctoral Thesis of UPI)
[3] National Council of Teachers of Mathematics 2000 Principles and standards for school mathematics (Reston: National Council of Teacher of Mathematics)
[4] Yee F P 2002 The role of problem to enhance pedagogical practice in Singapore mathematics classroom The Mathematics Educator 6 15-31
[5] Pimta S and Nuangchalerm P 2009 Factor influencing mathematics problem-solving ability of sixth-grade students Journals of Science 5
[6] Kirkley J 2003 Principles for teaching problem-solving (Indiana: Plato Learning, Inc)
[7] Committee on the Undergraduate Program in Mathematics 2015 Curriculum Guide to Major in The Mathematical Science (Washington DC: The Mathematical Association of America)
[8] Pativisan S and Niess M I 2007 Mathematical Problem-Solving Processes Of Thai Gifted Students Mediterranean Journal for Research in Mathematics Education 6 1-2
[9] Kleden M A 2015 Improve the ability of mathematical, logical thinking, mathematical communication, and disposition of self-directed student learning through metacognitive learning (Bandung: Doctoral Thesis of UPI)
[10] Widjajanti D B 2010 Analysis Of The Implementation Of Problem-Based Collaborative Lecture Strategies In Developing Problem-Solving Skills, Mathematical Communication, And Confidence In Mathematics Learning (Case Studies On Uny Mathematics Education Study Program Students) (Bandung: Doctoral Thesis of UPI)
[11] Karlimah 2010 Develop Mathematical Communication Skills And Mathematical Dispositions Of pgsd Students Through Problem-Based Learning (Bandung: Doctoral Thesis of UPI)
[12] Mahapoontanont N 2012 The Causal Model Of Some Factors Affecting Critical Thinking Abilities Procedia-Social and Behavioural Science 46 146-150
[13] Hasratuddin 2010 Meningkatkan Kemampuan Berpikir Kritis Siswa Smp Melalui Pendekatan Matematika Realistik. Jurnal Pendidikan Matematika 4
[14] Ratumanan T G 2015 Inovasi Pembelajaran Mengembangkan Kompetensi Peserta Didik Secara Optimal (Yogyakarta: Penerbit Ombak)
[15] Abdullah N Tarmizi R. and Abu R 2010 The Effects Of Problem-Based Learning On Mathematics Performance And Affective Attributes In Learning Statistics At Form Four Secondary Level Procedia Journal 8 370-376
[16] Cazzola M 2008 Problem-Based Learning And Mathematics: Possible Synergic Actions Proceeding ICERI2008-Spain
[17] Padmavathy R D and Mareesh K 2013 Effectiveness of Problem-Based Learning In Mathematics International Multidisciplinary e-Journal 2
[18] Setiawati E 2014 Develop The Ability To Think Logically, Creatively, And Habits Of Mind Mathematically Through Problem-Based Learning (Bandung: Doctoral Thesis of UPI)
[19] Indriawati I Ichsan M and Nugraheni N 2013 Penerapan Model Problem Based Learning (PBL) Untuk Meningkatkan Kualitas Pembelajaran Matematika. Joyful Learning Journal 2
[20] Hillman W 2003 Learning how to learn: Problem Based Learning Australian Journal of Teacher Education 28
[21] Fior N M 2015 Investigating and Foresting Metacognition in Early Math Learners. (Doctoral Thesis of University of Calgary)
[22] Murni A 2013 Improvement Of Problem-Solving Skills And Mathematical Representation Of Junior High School Students Through Soft Skills-Based Metacognitive Learning (Bandung: Doctoral Thesis of UPI)
[23] Nindiasari H 2013 Improve The Ability And Disposition Of Mathematical Reflective Thinking And The Learning Of High School Students Through Learning With A Metacognitive Approach (Bandung: Doctoral Thesis of UPI)
[24] Fatimah F 2012 Kemampuan komunikasi matematis Dalam pembelajaran statistika elemen ter melalui problem-based learning Jurnal Cakrawala Pendidikan XXXI