Comparison of mathematical literacy enhancement between students with problem-based learning and guided discovery learning model

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Abstract. Mathematical literacy is an individual’s capacity to formulate, employ and interpret mathematics in a variety of contexts. The purpose of this study was to review the comparison of enhancement in mathematical literacy between students who received problem-based learning and other group of students who received guided discovery learning based on initial mathematical ability in overall and level of initial mathematical ability (high, medium, and low). This research was conducted at a junior high school in Jakarta. The method used in this study was quasi-experimental with 66 students as the samples. The instrument used to collect the data was mathematical literacy test. The results showed that enhancement in mathematical literacy of the students receiving problem-based learning was higher than the students who received guided discovery learning based on initial mathematical ability on overall and those who started on medium level of ability. However, the enhancement in mathematical literacy of the students receiving problem-based learning was not higher than the students who received guided discovery learning based on high and low level of initial mathematical ability.

1. Introduction
Mathematics competences that can be grown through mathematics learning according to Permendikbud number 21 are as follow: 1) to show logical, critical, analytical, careful and thorough qualities; to be responsible, responsive, and to show perseverant attitudes in solving problems, 2) to have curiosity, spirit of continuous learning, self-confidence, and interest in mathematics, 3) to have trust on power and the use of mathematics, which is formed through learning experience, 4) have an open, objective attitude in group interaction or daily activities, 5) to have the ability in communicating mathematical ideas clearly, 6) to understand mathematical concepts [1]. The process of understanding mathematical concepts through reasoning, solving problems, and communicating ideas mathematically is a part of mathematical literacy. In other words, the purpose of learning mathematics in schools includes developing and honing students’ mathematical literacy in the learning process.

Mathematical literacy is an individual’s capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and
decisions needed by constructive, engaged and reflective citizens [2]. A person who has good mathematical literacy can use algorithms or mathematical knowledge. Their mathematical literacy is reflected in their habits and behaviour and how they deal with problems and situations. A person with good mathematical literacy can also estimate, interpret data, solve everyday problems, argue numerically, graphically, and geometric situations, and communicate using mathematics [3].

There are seven important components in the 2015 mathematical literacy assessment framework. These seven components are often referred to as the Fundamental Mathematical Capabilities (FMC) or basic mathematical abilities. These mathematical abilities are as follow: 1) communication, 2) mathematizing, 3) representation, 4) reasoning and giving argument, 5) devising strategies for solving problem, 6) using symbolic, formal and technical language and operations, and 7) using mathematical tools [4].

The most recent PISA results in 2015 for mathematics showed that Indonesia gained an average score of 386 and ranked 65th out of 72 countries. One of studies about mathematical literacy in Indonesia reported that mathematical literacy achievement of junior high school students is high on level one, medium on level two and three, and low on level five, while level six is not achieved at all. [5]. Another study states that junior high school students are difficult to do mathematization [6]. Based on the results of the PISA test and previous studies it can be said that in general the student's achievement of mathematical literacy in Indonesia is still low.

One of learning models expected to improve students' mathematical literacy is problem-based learning. Problem-based learning is the learning process that aims to prepare students to act as problem-solvers (self-directed problem solvers) who can work together with other students, exposing students to situations that can encourage them to be able to find problems, research, and solve them. This learning model is often used in Mathematics and Sciences researches [7]. The previous study revealed that the increase of students’ mathematical literacy ability in realistic-scientific approach with Edmodo group is better than the scientific approach group but less than the increase of students’ mathematical literacy ability in problem-based learning scientific approach group [8]. This indicates that the problem-based learning model can improve mathematical literacy. Other results of study stated that problem-based learning can improve students' reasoning and attitudes toward mathematics which are also parts of students' mathematical literacy components [9].

There are five stages of problem-based learning. These learning stages involve the process of interaction between students, teachers, and learning environment. Stages of problem-based learning are as follow 1) student's orientation on the problem, 2) organizing students to learn, 3) guiding individual and group investigations, 4) developing and presenting the work, and 5) analysing and evaluating the process of problem solving [10].

Guided discovery learning is a learning activity designed so that students can independently find concepts or principles through a mental process. The mental process includes the ability to observe, classify, make allegations, explain, measure, makes conclusions and so on [11]. The stages of learning in guided discovery learning are as follow: 1) teacher formulate problems that will be given to students with sufficient data, the formulation must be clear, he or she should avoid statements that cause misinterpretations so that the students will take correct direction, 2) students compile, process, organize, and analyse the data provided by the teacher, 3) students are asked to compile temporary answers or conjectures to the activities or problems raised, 4) the teacher checks the conjectures made by students to ensure that the conjectures are correct by controlling discussion activity in each group, and 5) after students find what they are looking for, the teacher should provide practice questions or additional questions to check whether the findings are correct [12]. This is in line with Kemendikbud that states that the stages of guided discovery learning are as follow: 1) stimulation, 2) problem statements, 3) data collection, 4) data processing, 5) verification, and 6) generalization [13].

One study about guided discovery learning reported that learning mathematics with discovery learning method in eight grade students of Junior High School could enhance the ability of mathematical literacy more significantly. Discovery learning gave chance to students to construct their own knowledge so they could understand mathematical problem up to its solutions [14]. Another
study revealed improvement in mathematics literacy shown in pre-test and post-test skills that indicates that the students are able to see difficult or unfamiliar things becoming easier. Therefore, discovery learning can improve the achievement on literacy competency [15].

The enhancement of mathematical literacy by using PBL model better than students who received conventional learning [16]. This is in line with others study that stated that there were no significant differences in the enhancement of the mathematical literacy skills of good students using both problem based learning and conventional learning [17]. Another study revealed that discovery learning with higher order thinking skill-oriented is qualified for student’s mathematical literacy [18]. The purpose of this study was to review the comparison of enhancement in mathematical literacy between students who were taught by Problem Based Learning (PBL) and other group of students who were taught by Guided Discovery Learning (GDL) learning based on initial mathematical ability in overall and level of initial mathematical ability (high, medium, and low).

Polyhedron chapter was used in this study. This chapter was selected because contextual problems which including in mathematical literacy test can be made with various forms. The problems depending on the topic so that the instruments can measure mathematical literacy appropriately. The contents of polyhedron in this study are: 1) the surface area of cuboid, cube, prism, and pyramid, and 2) the volume of cuboid, cube, prism, and pyramid.

2. Methods
This research is a quasi-experimental research with pre-test and post-test two treatments design. The design of the research is shown in Figure 1 [19].

| Experimental Group 1 | O₁ | X₁ | O₁ |
|----------------------|----|----|----|
| Experimental Group 2 | O₂ | X₂ | O₂ |

**Figure 1. The Data Description of Students’ Mathematical Literacy**

Descriptions:
- X₁ = Treatment (learning with problem-based learning model)
- X₂ = Treatment (learning with guided discovery learning model)
- O₁ = Measurement of mathematical literacy (in groups with problem-based learning model)
- O₂ = Measurement of mathematical literacy (in groups with guided discovery learning model)

---: The subject is not grouped randomly

The population in this study was all students of the eight grade of elementary school in Jakarta. The 66 peoples as samples were taken through purposeful sampling technique. One class that contained 33 students in total, selected as the first experimental groups who had taught with problem-based learning (PBL) model and another class, which amounted to 33 students, was selected as the second experimental groups who had taught with guided discovery learning model (GDL).

Initial mathematical ability (IMA) data was collected through IMA tests which were carried out before the two experimental groups were given treatment. IMA test results were used to classify students into groups of students with high ability, medium and low. Mathematical literacy data were obtained through mathematical literacy test that consist of five items of essay questions. Mathematical literacy test contained pre-test and post-test questions containing space and shape contents and occupational and personal contexts according to the aspects of mathematical literacy.

This research was conducted in eight meetings in each experimental group. The students were grouped based on their initial mathematical ability (high, medium, and low) which was obtained from IMA test. The pre-test was given to students in each of the experimental groups before being given a learning treatment. After it, the first experimental group was given problem-based learning model and the second experimental group is given guided discovery learning model. After that, both groups were given post-test in form of mathematical literacy test. After the data was obtained, then an analysis of
the enhancement of mathematical literacy were reviewed by researchers based on the overall, high, medium and low levels of IMA to make conclusions. The data analysis is done by SPSS version 21 with the significance level 0.05.

3. Result and Discussion
The results of students’ mathematical literacy pre-test and post-test are presented in Table 1. It can be seen that the average pre-test, post-test, and N-gain of students taught with the PBL model is higher than students who study with the GDL model. When viewed based on each IMA category, pre-test score in all categories of students who obtain PBL model are better than pre-test score of students who obtain mathematics learning with the GDL model. This shows that the average pre-test of the two classes is not much different. This indicates that the IMA of the two classes is relatively the same before being given treatment. The Post-test and N-gain averages of high and medium IMA level in students with the PBL model are superior compared to students with GDL model but the post-test and N-gain of IMA low level with GDL model turns out to be superior to students with PBL model.

Table 1. The Data Description of Students’ Mathematical Literacy

| IMA Categories | Statistics | PBL Group | GDL Group |
|---------------|------------|-----------|-----------|
|               |            | Pre-test  | Postest   | N-gain | Pre-test  | Postest   | N-gain |
| High          | N          | 4         | 6         |         |          |          |        |
|               | \(\bar{x}\) | 21.00     | 36.67     | 0.52    | 13.50    | 29.67     | 0.46    |
|               | S          | 12.17     | 8.39      | 0.22    | 3.27     | 10.97     | 0.28    |
| Medium        | N          | 21        | 22        |         |          |          |        |
|               | \(\bar{x}\) | 12.65     | 25.95     | 0.35    | 12.27    | 17.48     | 0.14    |
|               | S          | 2.03      | 7.27      | 0.19    | 2.73     | 7.11      | 0.20    |
| Low           | N          | 8         | 5         |         |          |          |        |
|               | \(\bar{x}\) | 11.63     | 18.75     | 0.18    | 11.50    | 19.50     | 0.21    |
|               | S          | 1.92      | 6.94      | 0.19    | 0.71     | 4.95      | 0.11    |
| All Categories| N          | 33        | 33        |         |          |          |        |
|               | \(\bar{x}\) | 13.18     | 25.36     | 0.33    | 12.55    | 20.09     | 0.20    |
|               | s          | 4.37      | 8.68      | 0.21    | 2.22     | 8.67      | 0.23    |

Maximum Score = 50

Normality test of the data N-gain of students’ mathematical literacy based on IMA data distribution calculated by Kolmogorov-Smirnov test (Table 2). Based on Table 2 it can be concluded that the data distributions of the N-gain Score Students’ mathematical literacy based on overall, medium, and low level of IMA in the PBL group and GDL group are normal distribution. The homogeneity test was done using Lavene test, the calculation results can be seen in Table 3.

Table 2. Normality Test Results of N-gain Score Students’ Mathematical Literacy based on IMA

| Kind of IMA | Model | Kolmogorov-Smirnov | Conclusion         |
|-------------|-------|--------------------|--------------------|
|             |       | Statistic | Df | Sig. |                       |
| overall     | PBL   | 0.096    | 33 | 0.200 | Normal Distribution   |
|             | GDL   | 0.123    | 33 | 0.200 | Normal Distribution   |
| high        | PBL   | 0.287    | 4  | 0.000 | Not Normal Distribution |
|             | GDL   | 0.290    | 6  | 0.125 | Not Normal Distribution |
| medium      | PBL   | 0.150    | 21 | 0.200 | Normal Distribution   |
|             | GDL   | 0.139    | 22 | 0.200 | Normal Distribution   |
Table 3. Homogeneity Test Results of N-gain Score Students’ Mathematical Literacy based on overall, medium, and low level of IMA

| Kind of IMA | Lavene Statistic | df1 | df2 | Sig. | Conclusion             |
|-------------|------------------|-----|-----|------|------------------------|
| Overall     | 0.116            | 1   | 64  | 0.735 | Variance of N-gain data in both groups is homogeneous |
| Medium      | 0.108            | 1   | 41  | 0.744 | Variance of N-gain data in both groups is homogeneous |
| Low         | 9.253            | 1   | 11  | 0.011 | Variance of N-gain data in both groups is not homogeneous |

The N-gain data based on overall and medium level of IMA are normally distributed and homogeneous. Then the next step is to test the average difference in both classes to find out whether there are differences in the average N-gain in the two groups using Compare Mean Independent Sample t-Test. The hypothesis proposed is as follows: $H_0: \mu_{PBL} \leq \mu_{GDL}$ and $H_1: \mu_{PBL} > \mu_{GDL}$ (Table 4). Table 4 shows that $H_1$ is accepted, in other word the enhancement of students’ mathematical literacy based on overall and medium level of IMA with PBL model is higher than GDL model.

Table 4. Independent Sample t-Test Results of N-gain Score Students’ Mathematical Literacy based on overall and medium level of IMA

| Kind of IMA | t-test for Equality of Means | Conclusion |
|-------------|-------------------------------|------------|
|             | T                | Df | Sig. (2-tailed) |          |
| Equal Variances Assumed | Overall | 2.346 | 64 | 0.022 | $H_0$ rejected |
| Medium      | 3.602            | 41  | 0.001 | $H_0$ rejected |

The N-gain data in high level of IMA are not normally distributed according to table 2, then the next step is to test the average difference in both classes to find out whether there are differences in the average N-gain in the two groups using Mann Whitney U test. The hypothesis proposed is as follows: $H_0: \mu_{PBL} \leq \mu_{GDL}$ and $H_1: \mu_{PBL} > \mu_{GDL}$ (Table 5).

Table 5. Mann Whitney U-Test Results of N-gain Score Students’ Mathematical Literacy based on IMA high level

| Mann-Whitney U | Asymp.Sig.(2-tailed) | Conclusion |
|----------------|----------------------|------------|
| 7.000          | 0.286                | $H_0$ accepted |

Table 6 shows that $H_1$ is rejected, in other word the enhancement of students’ mathematical literacy based on IMA high level with PBL model is not higher than GDL model. The N-gain data in low level of IMA is normally distributed and not homogeneous according to table 2 and 3, then t’-test was done. The hypothesis proposed is as follows: $H_0: \mu_{PBL} \leq \mu_{GDL}$ and $H_1: \mu_{PBL} > \mu_{GDL}$ (Table 6).

Table 6. Independent Sample t-Test Results of N-gain Score Students’ Mathematical Literacy based on IMA low level

| t-test for Equality of Means | Conclusion |
|-----------------------------|------------|
| Equal Variances Not Assumed | T | Df | Sig. (2-tailed) | $H_0$ accepted |
|                            | -0.277    | 10.143 | 0.787 | $H_0$ accepted |
Table 6 shows that $H_0$ is rejected, in other word the enhancement of students’ mathematical literacy based on IMA low level with PBL model is not higher than GDL model. Based on the results of the research data analysis, the average achievement of students' mathematical literacy in the PBL group is 25.36 while for the GDL class it is 2.09 with 50 for ideal maximum score. In other word the achievement of mathematical literacy with the PBL model reaches 50.72% of the score ideal maximum. Meanwhile the enhancement of student mathematical literacy in the PBL group is 0.33 with medium enhancement category while GDL group is 0.20 with low enhancement category. This means that the two learning models have a positive influence on students' mathematical literacy. This is supported by previous study which stated that learning by using problem-based learning model can improve students' mathematical literacy [20], and another finding by Babys which is stated that mathematical literacy from students taught using Discovery Learning model with RME-PISA approach better than the class taught by the RME model and better than the class taught by expository [21].

Moreover, it was found that the enhancement of mathematical literacy students with high IMA level in PBL group was not higher than the GDL group. This may be due to several factors and among them is the situation in the field at the time of the study. The researchers observed that students with high IMA level in the PBL model seemed to always be peer tutors for other friends in their group of discussion. They always looked more dominant in discussions and assisted other friends who were still unable to solve contextual problems. This caused the students with high IMA level in PBL groups had less time to practice math questions on worksheet or teaching materials given so that their post-test scores did not reach significant differences with pre-test scores.

The students with medium IMA level in PBL group had a higher enhancement in mathematical literacy than the GDL with enhancement difference of 0.21. This meant that students with medium IMA level had greater differences in the enhancement of mathematical literacy compared by high IMA level. Furthermore, students with low IMA level in GDL had a higher enhancement in mathematical literacy compared to students in the PBL with enhancement difference of 0.03. This was because students with low IMA level in the GDL group felt to be helped by the teacher's guidance process when learning took place. Conversely, students with low IMA level in PBL group tended to feel anxious when faced directly with the learning process that required students to be able to solve contextual mathematics problems independently. They found it difficult to follow the learning path because of limited mathematical abilities.

Another finding in this study is the increase in students' mathematical literacy with low IMA level was higher than students with medium IMA level in the GDL group with enhancement difference of 0.07. This indicates that learning with the GDL model is recommended as one of the learning models that can improve students' mathematical literacy at low IMA level. Another causes for the higher enhancement in mathematical literacy of students in PBL is the PBL model is a model that always gives students contextual problems that are characteristic of the problem of mathematical literacy. In other words, PBL develops problem solving skill. In line with Ruchaidi which is stated that PBL increases students' heuristic which is a problem solving strategy [22]. Furthermore, PBL facilitates students independently to transform contextual problems into mathematical problems or models that is called mathematization, collect data and conduct investigations through group discussions until finally finding new knowledge themselves. This is in line with the findings of Botty who revealed that the implementation of PBL motivates students to collaborate and learn in peer groups so that gradually able to reduce student dependence on teachers in discovering new knowledge [23].

Different conditions with PBL model, GDL model does not optimize students independently to build their knowledge independently. The discovery of the concept is guided by the teacher with a presentation of the problems that have been formulated. Moreover, learning with GDL does not sharpen students' mathematical skills. The problems given are not always use contextual problems. This resulted in students' mathematical literacy being less honed.

According to this study result the suggestions that can be provided are: 1) problem-based learning is more recommended to enhance students’ mathematical literacy than guided discovery model
although GDL can improve students’ mathematical literacy also, 2) learning with PBL needs a long time to do, so the teacher should adjust between the time available and the portion of material that will be discussed in each meeting, and 3) The results of achievement and enhancement of mathematical literacy are not optimal. Therefore, there is a need for further research that compares cognitive load between students who obtain PBL and GDL models.

4. Conclusion
It can be concluded that based on overall initial mathematical ability, the enhancement of mathematical literacy of PBL models was higher than the students who obtained GDL model. Based on high level of initial mathematical ability, the enhancement of mathematical literacy of PBL models was not higher than the students who obtain GDL model, while based on medium level of initial mathematical ability, the enhancement of mathematical literacy of PBL models was higher than the students who obtained GDL model. Moreover, based on low level of initial mathematical ability, the enhancement of mathematical literacy of PBL models was not higher than the students who obtained GDL model. So the use of PBL model had a significant effect on students' mathematical literacy.

5. References
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