The students’ mathematical reasoning ability based on problem based learning model

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Abstract. This research aimed to develop Mathematics instructional instruments by using problem based learning (PBL) on “straight line equation” Learning Material for the eighth grade of Secondary schools well as to know its effect on the students’ mathematical reasoning ability. The method used is mixed methods with concurrent triangulation strategy model namely development research method with Thiagarajan model combined with quantitative method. The research subjects were the students of MTsN 5 Jember of Jember regency consisting of 31 students of trial class 31 of experimental class and 31 students of the control class. The instruments of this research are a observation, an test, and an interview. Quantitative method is applied to analyze the difference of student achievement result among two classes are experimental class and control class, while the qualitative method is applied to describe the process and results of problem-based learning development. The product of this study is the problem based learning teaching administrations. The validity of the average value of those teaching administrations (lesson plan, the students’ worksheet, THB) is 3.75. The research results showed that: (1) the instructional instruments resulted is valid, the implementa-tion of the instructional instruments is in practical and effective; (2) the significance value (2-tailed) is 0.000 (p < 0.05), which indicated that the application of learning by using PBL had a significant effect on the students’ matematical reasoning ability.

1. Introduction
Education is an important role in human life and their progress. A country can achieve an improvement if the education in the country has a good quality. The development of science and technology is based on mathematics, where Mathematic is the study of regularity system, both systems in nature and in the human mind. The development of mathematics has an impact on expanding the critical thinking that requires the readiness of the teachers and students to face the challenges of the globalization era and learning mathematics in school is expected to be able to establish and train students’ mindset and reasoning.

Reasoning is a thought process to draw conclusion from existing facts through various ways that are recognized the truth .Whereas the reasoning competence is a competence to make connections among knowledge, information, and experience and after being involved in analysis process, synthesis, and evolution, to make logical decisions based on information. Reasoning competence is an integral part from social development because it directly influences the use of one’s discretion in information processing and encourages logical decisions based on information and facts that have been analyzed [1]. Reasoning is one of basic competence of mathematics. Reasoning is a thinking process through several facts or the principle toward to conclusions and closely related to mathematics
material. As stated in Ministry of National Education that mathematics material and mathematics reasoning are two inseparable things, namely mathematics material is understood through reasoning and reasoning is understood and trained through learning mathematics material. Thus, reasoning competence is an important role in understanding and solving mathematics problems.

Table 1. Indicator of Mathematics reasoning competence.

| No | Reasoning Indicator                  | Description                                                                 |
|----|--------------------------------------|-----------------------------------------------------------------------------|
| 1  | Presenting conjectures                | • the subject can make assumptions by writing down and mentioning logical reasons or the alleged answers given |
| 2  | Performing mathematical manipulations | • use mathematical expressions to express mathematical ideas                  |
| 3  | Giving reason or evidence of the truth| • the subject is able to write down and mention the truth of the opinions given |
| 4  | Drawing conclusions and statements    | • the subject is able to write down and mention formulas / patterns to make generalizations |

The importance of having mathematical reasoning competence on students is basically one mathematics vision, especially to comply the future requirement. Mathematics learning is directed to provide opportunities for developing reasoning competence, awareness of mathematics utility, fostering self-confidence, objectives and open minded to face the changing future constantly. Learning in the 21th century was a transition learning in which curricula developed today require schools to change teaching-centered learning approaches to be learner-centered learning.

Problem based learning (PBL) has been defined as a method of inquiry in which the students solve difficulties, oddities, and problems in a real context, furthermore, that it enables students to develop their curiosity and team work competence [2]. Problem based learning (PBL) is a cooperative learning model that uses real problems as a context for using critical thinking of students on learning and solving problem skill [2]. In addition, the learning model (PBL) applies a creativity and collaboration in a discussion group to solve the problems [3]. In the team work, they face some ideas, solving techniques, share the knowledge gained, and perfect each other. Thus, PBL does not presume solely problem solving but it is a strategy that has a considerable contribution in enriching and understanding. Problem based learning is a teaching method that consists of utilizing “real world” problems such as the context needed, so the students “learn” critical thinking and problem solving abilities and to assimilate important concepts for various disciplines of study. By practicing PBL, students acquire long term learning skill, which include the capacity to identify and use adequate learning [4]. Based on the opinion of the experts, it can be interpreted that the model of problem based learning (PBL) is a series of activities that emphasize the process of solving the real problem faced.

One of the effective learning is Problem Based Learning (PBL) model. The PBL model stimulates students to improve their reasoning competence. Because PBL is learning that based on the problem, it requires the students to use their high thinking with reasoning competence. Reasoning is an important process and is used by students in solving mathematics problem [5]. As for the regulation of the Director General of Elementary Education, Ministry of National Education Number 506/C/Kep/PP/2004 detailing the reasoning competence in indicators of mathematics [6]. The indicators of mathematics reasoning competence that used in this study consisted of four indicators, including: 1) presenting conjectures, 2) performing mathematical manipulation, 3) giving reasons or evidence of the truth, 4) drawing conclusions and statements.
Indicator of mathematics reasoning competence that has been discussed in theory can be improved through learning by using Problem Based Learning. It caused the stages in Problem Based Learning model include (1) orientation students on problems; (2) orienting students to learn; (3) guiding individual and group inquiry; (4) developing masterpiece; (5) analyzing and evaluation. The core activity in PBL that has been discussed by Ministry of Education and Culture is one of the main factors in developing reasoning competence.

2. Method
The method used in this study is a combination or mixed method. The combination method is a combination of quantitative and qualitative research methods used in research activities [7]. The research design uses R&D (Research and Development) namely Thiagarajan, in this method it consolidates 2 types of research: Development Research (R&D) and experimental research. Development Research using the 4-D model developed by Thiagarajan and Semmel consists of 4 steps, namely: of define, design, develop, and disseminate [8]. We started the research by determining three classes of MTs students as the test, experiment and control classes. They consisted of 31 students from trial class, 31 from the experimental class and 31 students from the control class. in the first stage, the problem-based teaching administrations is tried in the trial class, after the device is declared valid, practical, and efficient, the researcher teaches the problem-based learning model in the experimental class, to find out whether there is an effect of problem-based learning on students' mathematical reasoning abilities.

The following figure describes the research design.

![Diagram](image)

**Figure 1.** Research design.

**Information:**

- **X**: teaching and learning processes that use the problem-based mathematics learning media
- **O1**: Test scores for students' mathematical reasoning ability taught using problem-based learning media.
- **O2**: Test scores for students' mathematical reasoning ability taught without using learning media based on problem learning.

**Population**
The population in this research is eight grade of MTs Negeri 5 Jember are VIII A, VIII B, VIII C, VIII D. After conducting homogeneity tests, researchers determined three classes are the trial class and the experimental class. the trial class is used to find out teaching administrations used had fulfilled valid, practical, and effective. Trial class is used to determine the administration of teaching used has met valid, practical, and effective. then, after teaching administration has been declared valid, practical, and effective, learning continues in the experimental and control classes. in experimental class learning using problem-based learning models. while the control class without using the problem based learning model of learning.

**Instrument**
The data sources are mathematics teachers, expert valuator, students’ reasoning observation sheet, observations of teacher activities, students’ questionnaires and the result of the research. The method of collecting data is used in this research consist of observation, questionnaire, interview, test and documentation. The research instrument is a validation, interview, the student’s reasoning observation, the teacher activity observation, questionnaire student’s response, and the result of test.
Tasks

To measure the level of students' mathematical reasoning, questions are needed that include four indicators of mathematical reasoning and these questions can measure the level of students' mathematical reasoning, which consists of three categories: high, medium, low. The questions used are questions that are not commonly done by students in school, namely questions that are in accordance with indicators of reasoning and which are related to problem-based learning, namely exercises related to daily life. In this case, the material used is a straight line equation. The following will explain one example of exercise number 1, which is related to the first indicator, which is to propose guesses.

The position of the school is known in Indonesia Jember area based on eye direction wind as follows.

• School A is located in the east with a distance of 3 km from the town square jember.
• School B is located to the north with a distance of 2 km from the town square jember.
• School C is located in the east with a distance of 9 km from the town square jember.
• School D is located in the North with 6 km away from the town square of Jember.
• AB is a straight path connect school A with school B.
• CD is a straight line connecting between schools C with school

Hint: suppose the town square Jember as point O (0, 0)

a. Do you think AB is parallel? CD? Explain your answer!

Students are asked to guess whether point AB is parallel to point CD. Then students are asked to prove from this charge. AB is parallel to CD because it shows that AB and CD have the same slope. To show AB is really parallel to CD is to calculate AB and CD gradient, namely:

\[
m_{AB} = \frac{(0 - 2)}{(3 - 0)} = -\frac{2}{3}
\]

\[
m_{CD} = \frac{(0 - 6)}{(9 - 0)} = -\frac{6}{9} = -\frac{2}{3}
\]

\[
m_{AB} = m_{CD} = -\frac{2}{3} \text{ so AB is parallel to the CD.}
\]

The qualitative data analysis conducted with analyzes the validation, practice, and effectiveness. Analysis of students’ mathematics reasoning competence uses indicators of mathematics reasoning competence that consist of presenting conjectures, performing mathematical manipulations, giving reason and evidence of the truth, and drawing conclusions and statements. On the other hand, analysis quantitative data is done using the Normality Test technique with a sample Kolmogorov-Smirnov. If the score of normality test has a normal distribution, statics analysis that used is parametric statics, namely independent sample t-test technique. Otherwise, if the data does not have a normal distribution, the static analysis used is nonparametric statics technique, used the mann-Whitney test.

3. Research Findings

The first phase used in this study is qualitative method namely development learning instruments using Thiagarajan model with four phases; define, design, develop, and disseminate. However, this research only reached the development stage and has not reached the dissemination stage yet. The developed learning media are lesson plan, worksheet, and achievement test.

The data in this research, learning media that based on problem has been developed is lesson plan, worksheet, and achievement test. The assessment of learning media is done by 3 valuators that consist of a math teacher and two lecturers. The used comment and suggestion valuators is to revise learning media that developed by the researcher. The result of assessment from 3 valuators state that learning media is proper and be able to use for research. These are the result of the validation analysis of lesson plan, worksheet and achievement test from three valuators as follow:
Based on the assessment results presented in the table, it can be explained that the administration of teaching to be used is in a valid category. lesson plans, student worksheets, and THB, validator 1 assesses the administration of teaching with a valid category that is the value of lesson plans 3.75, student worksheets 3.75 and THB 3.58. then the average value of validation is 3.69 at intervals $3 \leq V_r \leq 4$. validator 2 assesses the administration of teaching with a valid category that is the value of lesson plans 3.8, student worksheets 3.9, and THB 3.8. then the average value of validation is 3.83 at intervals $3 \leq V_r \leq 4$. validator 3 assesses the administration of teaching with a valid category with a lesson plan value of 3.71, student worksheets 3.86, and THB 3.81. the average value of validation is 3.79 at intervals $3 \leq V_r \leq 4$. then, it can be concluded that the final results of the three validator assessments are 3, 77 which means the problem based teaching administrations is declared valid.

Validated learning media is applied in the trial grupand experimental group, while the control group applies conventional learning.

This is the result of learning mathematical reasoning competence in the experimental and control groups.

![Diagram of validator's assessment result.](image)

**Figure 2.** Diagram of validator’s assessment result.

### Table 2. Value of mathematical reasoning ability descriptive statistic.

| Description      | N   | Mean  | Std. Deviation | Minimum | Maximum |
|------------------|-----|-------|----------------|---------|---------|
| experiement      | 31  | 78.71 | 11.028         | 55      | 100     |
| control          | 31  | 66.13 | 9.461          | 45      | 85      |

Based on table 2, it was explained that the results of the experimental group were higher than the control group. The highest score obtained in the experimental group was 100 and the lowest score was 55, while the control group with the highest score was 85 and the lowest score was 45. That is, the exhaustiveness of the mathematical scores was at least 75, meaning that in the experimental class students who did not complete had the lowest scores ie 55. while in the control class students who did not complete had the lowest value of 45. Then the results were analyzed using the Kolmogorov Smirnov test with SPSS version 21 to determine the results of mathematical reasoning abilities that have a normal distribution. or not. This is the result of the normality test using the Kolmogorov-Smirnov test.
Table 3. Normality test results mathematical reasoning learning outcomes one-sample Kolmogorov-Smirnov test.

| One-Sample Kolmogorov-Smirnov Test | Experiment | Control |
|-----------------------------------|------------|---------|
| N                                 | 31         | 31      |
| Normal parameters\(^{a,b}\)       |            |         |
| Mean                              | 78,71      | 66,13   |
| Std. Deviation                    | 11,028     | 9,461   |
| Most extreme differences          |            |         |
| Absolute                          | ,116       | ,116    |
| Positive                          | ,116       | ,096    |
| Negative                          | -,105      | -,116   |
| Kolmogorov-Smirnov Z              | ,644       | ,646    |
| asymp. Sig. (2-tailed)             | ,802       | ,798    |

- a. Test distribution is normal.
- b. Calculated from data.

Figure 3. Histogram of experiment class and control class.

Based on Figure 3, it can be concluded that data (histogram) follows the pattern of curve normal so can be said that data is distributed normal. And the result of the kolmogorov-Smirnov test has been presented in table 3 that on Asymp. Sig. (2-tailed) is 0.802 for experimental group and 0.798 for control group. The result of the experimental and control group had significant because both of the data more than > 0.05, it means the data is normal distribution. After that, determine the hypothesis by looking at the result of data is it normal distribution or not. If the data is normal distribution and homogeneous then the test uses parametric test that is independent sample t-test, and if the data is not normal distribution then it uses a non-parametric test that is the Mann-Whitney test. From the table above, the result of the experimental and control group had significant level, it means the data is normal distribution, so the hypothesis used is independent sample t-test.
Table 4. Test results independent sample t-test.

| Levene's Test for Equality of Variances | t-test for Equality of Means |
|----------------------------------------|-----------------------------|
| F           | Sig.  | t   | df | Sig. (2-tailed) | Mean difference | Std. error difference | 95% Confidence interval of the difference |
| Equal variances assumed                  | 0.914 | 343 | 4,821 | 60 | 0.000 | 12,581 | 2,610 | 7,360 | 17,801 |
| Mathematical reasoning                   | 4.821 | 58,645 | 12,581 | 2,610 | 7,358 | 17,803 |

Based on the Table 4, it can be seen that Sig. the Levene test for homogeneity is 0.343 > 0.05 so it can be concluded that the result of mathematics reasoning competence is homogeneous. In the equal variances assumed, the Sig. (2-tailed) of 0.000 < 0.05. Because the significance score is less than 0.05, then H0 is rejected and Ha is accepted, it means there is a significant difference between the control and experimental group in learning mathematics reasoning competence. The result of mathematics reasoning competence in experimental group is better than the control group. In experimental group used learning media that have been developed on their lesson plan, worksheet, and achievement test. Furthermore, learning media can be qualified if they get practicality criteria. Learning media can be practical if the developed learning media must be tested in the learning process using based problem. The test was conducted in eight grades as an experimental group and had 3 meeting. On first meeting discussed about straight-line equation, the next meeting discussed about gradients, and the last meeting discussed the relation of gradients to straight-line equations.

**Learning process**

In the experimental class students work together, ask questions and collaborate in solving problems given, to each group. The activities of students asking questions and explaining and sharing opinions in groups are presented in Figure 4. taken from one of the groups as a sample.

Figure 4. Activity on discussing in the experiment class.
Group discussions in the experimental class went smoothly where students collaborated to exchange ideas. Point B is the central point to exchanging opinions and explaining to students who lack understanding. In the experimental class, it is also seen that student D and student C are very enthusiastic about helping and explaining to student A. This shows that students have been able to collaborate well.

In the final learning, the teacher gives achievement tests in the control class and in the experimental class, the learning achievement test has been validated by experts. The results of this learning test in the form of a description prepared to measure the level of mathematical reasoning ability of students. Student answers were analyzed based on assessments on mathematical reasoning ability indicators. This is intended to classify students' mathematical reasoning abilities in the control class as well as the experimental class.

**Table 5. Categories of mathematical reasoning ability in experimental class students.**

| Value | Category    | Frequency | Percentage |
|-------|-------------|-----------|------------|
| 81-100 | Very Good  | 14        | 45.16%     |
| 61-80 | Good        | 15        | 48.38%     |
| 41-60 | Enough      | 2         | 6.45%      |
| 21-40 | Less        | 0         | 0%         |
| 0-20  | Very less   | 0         | 0%         |
| Total |             | 31        | 100%       |

**Table 6. Categories of mathematical reasoning ability in control class students.**

| Value | Category    | Frequency | Percentage |
|-------|-------------|-----------|------------|
| 81-100 | Very Good  | 1         | 3.2%       |
| 61-80 | Good        | 22        | 70.9%      |
| 41-60 | Enough      | 8         | 25.8%      |
| 21-40 | Less        | 0         | 0%         |
| 0-20  | Very less   | 0         | 0%         |
| Total |             | 31        | 100%       |

To determine the difference between the control class and the experimental class, statistical analysis was performed with an Independent Sample T-test. The results of statistical analysis show the significance value (2-tailed) shows the number 0.000. This means that the significance value is less than 0.05 and it can be concluded that there is a significant difference in students' mathematical reasoning abilities between the control class and the experimental class. The results of statistical analysis with the T-test can be seen in Table 4.

There are several problems when learning research process on experimental and control group. In experimental group, learning process is based on the lesson plan, and every group can finish the worksheet based on the step that has been given. But, some students have to be considered for developing mathematics reasoning competence on solving the problem. And in control group, the activity is less active and monotone. It caused the learning model applied is a conventional learning model. The explanation of the material using lecturing method, the students is less active on learning process. In addition, students’ attentions are uneven, students who sit at the back do not pay attention to the teacher, and they learn passively. While students who sit at the front, they get full focus on the
explanation. And the students are less active on answering the question. These are the recapitulation results of the activities in experimental and control group.

From the table above can be explained that the result of practical learning media can be obtained from the assessment on control group is 74.47%. And experimental group is 89.93%.

Lesson plan, worksheet and achievement test can be qualified if the learning media occupy the criteria of effectiveness. The effectiveness of developed learning media can be determined by analysis the data from the responses' students. There are the results of effectiveness analysis as follows on table 3.

The student questionnaire was filled by 31 students. Based on the results of the responses that have been presented in figure 4, the learning media can be called effective because students who give positive responses are ≥ 80% i.e. 87%. So it can be concluded that students provide positive responses and effective learning media, it means that learning using PBL model is more effective than conventional learning, this statement is in line with this state analyze about the effectiveness of PBL and find that PBL is more effective than conventional learning when the result is focused on retention of long-term knowledge [9].
4. Discussion
This is in line with the statements of Meke, Wutsqa, & Alfi that one of the advantages of using the Problem Based Learning (PBL) learning model is to develop student learning about critical thinking and problem solving skills [10]. Meanwhile according to Wahyuni & Susanto Reasoning it self is an important process used by students in solving mathematical problems [5]. Therefore PBL learning
model can stimulate students to improve reasoning abilities. This is because PBL is problem-based learning so that it requires students to think highly with their mathematical reasoning abilities. This is also supported by the research results of Cloud, R Hussain, & H Anwar, Nadeem (2017) which states that the learning model of problem based learning can improve critical thinking skills and problem solving in chemistry, but Cloud, R Hussain, & H Anwar, Nadeem also explained that PBL can also improve problem solving skills in mathematics in junior high school students. The results of the study generally showed that the PBL learning model was better than ordinary learning.

5. Conclusion
Based on the research, it can be conclude that there is significant effect of using problem based learning (PBL). The effect of mathematics reasoning competence is valid, practical, and effective criteria. The significant on independent test t-test sample is $0.000 \leq 0.05$, it means $H_0$ is rejected and $H_a$ is accepted, it can be concluded that the result of student’s reasoning mathematical on group experiment is better that control group.

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