The Effectiveness of Problem-based Learning Using Manipulative Materials Approach on Cognitive Ability in Mathematics Learning

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Abstract. This study aims to describe the more effective learning model between problem-based learning model using manipulative materials model and problem based learning for junior high school students' in term of cognitive ability. This quasi-experiment use the quantitative approach (pretest-posttest with nonequivalent group design) with two treatments: the experimental class using problem-based learning with manipulative material and the control class using problem-based learning. The effectiveness of treatments in both classes was analyzed used one sample t-test with 5% of the significance level. To test the comparison between the experimental class and the control class, the data analysis using an independent sample t-test with a 5% significance level. The result of this study shows that the problem-based learning using manipulative materials and problem-based learning, both are effective in term of students' cognitive abilities in learning mathematics. This study obtained that class with problem-based learning using of manipulative material is more effective in term of students' cognitive abilities in mathematics.

1. Introduction
One factor of mathematics learning result obtained from the cognitive aspects [1,2]. Cognitive is a view of students' thinking processes, where they remember, connect, process information, store information, compile understanding, combine newly received information with existing information to acquire knowledge [3,4]. Knowledge is the product of cognitive ability [5]. Cognitive ability is a knowledge-conducive belief-forming process [6]. Cognitive ability is the tendency of students' to process new information they received with the information they have ever experienced before. The information then processed, including students' understanding of the obtains information, modifies, reinforces, detailed the initial knowledge and interprets that to the new knowledge [7,8,9].

Bloom [10] view cognitive abilities as learning demonstrated of a memory of intellectual knowledge and skills include understanding information, organizing ideas, applying knowledge, analyzing and synthesizing data, choosing alternatives in problem-solving and evaluation the ideas or actions. Furthermore, taxonomy created by Anderson & Krathwohl [11] was revised of Bloom's taxonomy. This taxonomy involves two basic dimensions. The first dimension are knowledge dimensions involving four types of knowledge: factual knowledge (the basic elements student must know to be acquainted with a discipline or solve problems in it), conceptual knowledge (The interrelationships among the basic elements within a larger structure that enable them to function...
together), procedural knowledge (student uses their skills in using appropriate algorithms, techniques, and methods to find a solution from the given task), and metacognitive knowledge (Knowledge of cognition in general as well as awareness and knowledge of one’s own cognition) [11]. The second dimension is the knowledge process dimension involves six knowledge processes consisting of remember (retrieve relevant knowledge from long-term memory), understand (construct meaning from instructional messages, including oral, written, and graphic communication), apply (carry out or use a procedure in a given situation), analyze (break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose), evaluate (make judgment based on criteria and standards) and create (put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure) [11].

A learning environment that encourages students to gather practical experience through relationships with the real world related to daily life students can improve students' cognitive abilities in learning mathematics [3]. In addition, learning media are needed to help students understand the abstract concept to be more concrete and improve their ability to understand mathematics and explore mathematical concepts [12]. Therefore Problem Based Learning (PBL) using manipulative materials becomes one of the recommended learning. PBL use real-life problems as the main learning issue, which is related to students' real life that is felt to need a solution [13, 14]. Information processing theory and collaborative learning are available in PBL's theoretical framework. In a collaborative, students work together from the problem to understanding, applying concepts, analyzing and evaluating the significant steps of solutions and creating a new concept of the learning process [15, 16, 17]. Rochani and Abadi [18] in their research state that Problem Based Learning in mathematics highly effective in cognitive learning the dimensions of knowledge, understanding, and application for students’ in grades VIII.

Other than PBL, the manipulative material becomes one of the learning media can be used to improve students' cognitive abilities in the mathematics learning process. The manipulative material is a concrete object that can see, touch and helps students understand the concepts in mathematics to be more real and concrete [19,20]. Manipulative material support students in improving the dimensions of students' factual, conceptual and procedural knowledge. Manipulative material support students in improving the dimensions of students' factual, conceptual and procedural knowledge. The manipulative material can improve the dimensions knowledge process in remembering information, understanding information, and apply the right mathematical concepts [21,22]. Manipulative materials make students’ willing to share ideas and explore mathematical concepts. They ask and answer high-level thinking questions including analyzing, understanding and applying mathematical concepts [23].

Based on the description, then the implementation of problem-based learning using manipulative materials is important to be studied. Based on the description, then the implementation of Problem-based learning using manipulative materials and problem-based learning is very important to be studied. Problem-based learning with the use of manipulative materials expected to help students' find solutions to real-life daily issues raised in learning and improve student's cognitive ability. This study aims to obtain the more effective learning model between problem-based learning models with the use of manipulative materials and problem based learning in term of cognitive abilities for junior high school students’.

2. Method
This type of research is quantitative research with a quasi-experiment research design in term of students’ cognitive ability in probability. The research design used pretest-posttest with nonequivalent groups design with two treatments. The research process in two classes includes control class used problem-based learning and experimental class used problem-based learning model with the use of manipulative materials. The subjects of this research are students of class VIII in Mater Inviolata Larantuka junior high school (Larantuka is a small town located along the coastline whose population is a pluralistic society, with their main livelihoods being farming and fishing) totaling 35 students’ in the control class and 31 students’ in the experimental class.
Data collection techniques in this study were by given pretest and posttest to experimental class and control class. Tests are given to rate students' mathematical cognitive abilities in probability for junior high school students' in grade VIII. Pretest and posttest of cognitive ability using Anderson and Krathwol taxonomy of students' cognitive ability, consist of 18 items include 12 multiple choices (remembering, understanding, and applying) and 6 test description (analyzing, evaluating, and creating) [24]. Face validity pretest and posttest cognitive abilities validated by three supervisors. The construct validity of the posttest cognitive abilities in the medium category (Mean P = 0.655) and the pretest cognitive abilities in that category is (Mean P = 0.599) [25]. Item discrimination for multiple-choice pretest are reasonably good (Rpbis = 0.358) and also for multiple-choice posttest (Rpbis = 0.392) [26]. Reliability for pretest of cognitive ability give Alpha = 0.755 for multiple choice and alpha = 0.912 for description test. Reliability for posttest of cognitive ability given alpha = 0.733 for multiple choice and alpha = 0.896 for description question [27].

Test normality and homogeneity of the data obtained from the pretest and posttest of both classes. The normality test used Kolmogorov-Smirnov, while the homogeneity test used the Levene statistic. One sample t-test was used to determine the effect of PBL with the use of manipulative materials (experimental class) and PBL (control class) in students' cognitive mathematical abilities. Learning effective if the average score (μ) > 75. Independent sample t-test used to obtain more effective learning model between experimental class and control class.

3. Result and Discussion

The findings of this study mainly based on experimental data gathered from the respondents. Two performance tests conducted and the following the score tests for each class, the PBL using manipulative material class and the PBL class. The comparison for mean performance between the PBL with manipulative class and the PBL class are shown descriptively in Table 1.

| Test   | Class                  | n  | M   | SD  |
|--------|------------------------|----|-----|-----|
| Pretest| PBL using Manipulative | 31 | 29.97 | 8.25 |
|        | PBL                    | 35 | 26.79 | 7.43 |
| Posttest| PBL using manipulative | 31 | 80.48 | 6.06 |
|        | PBL                    | 35 | 77.23 | 6.16 |

Table 1 shows the descriptive rate of cognitive ability overall performance in two classes of students’, PBL using manipulative materials and PBL. Posttest data obtained that PBL uses manipulative materials and PBL give a positive effect on students’ probability performance. Besides, PBL with manipulative class performed better than PBL class.

The significance value in the Kolmogorov-Smirnov test of students' cognitive abilities in pretest data is > 0.05 for the experimental class (p-value = 0.067) and the control class (p-value = 0.200). It means pretest data normally distributed. The significance value of the variance homogeneity test on Levene at pretest data is 0.411 greater than 0.05. The assumption test fulfilled includes normality test and homogeneity test for pretest data, so the treatment in both classes in this study can be applied. The significance value in the Kolmogorov-Smirnov test of students' cognitive abilities in posttest data is > 0.05 for the experimental class (p-value = 0.200) and the control class (p-value = 0.200). It means posttest data normally distributed. The significance value of the variance homogeneity test on Levene at posttest data is 0.919 greater than 0.05. The assumption test fulfilled includes normality test and homogeneity test for posttest data, so one sample t-test in both classes in this study can be applied.

The increase in student learning activities in the classroom has a positive impact on students' cognitive abilities in mathematics. In this study, the cognitive abilities of both classes find effective...
from the results of one sample t-test after treatments (posttest data) give significance value <0.05. Details of one sample t-test results shown in Table 2.

Table 2. One sample t-test cognitive ability students’ performance from the PBL using manipulative material and PBL.

| Class                     | n  | t    | Sig. |
|---------------------------|----|------|------|
| PBL using manipulative    | 31 | 5.03 | 0.00 |
| PBL                       | 35 | 2.14 | 0.019|

Based on Table 2, the results of the significance value for the cognitive ability variable in students’ mathematics learning obtained less than 0.05. It shows that PBL with manipulative materials and PBL, both are effective in term of students’ cognitive ability in mathematics learning. Based on the results of the independent sample t-test obtained the significance value of the result for cognitive ability = 0.0175 < 0.05 (t = 2.153). It means that problem-based learning with the use of manipulative materials is more effective than problem-based learning on mathematical cognitive abilities.

Description of students’ cognitive abilities in multiple-choice analyzed based on students’ cognitive abilities including remembering, understanding and applying knowledge. Description of cognitive abilities in descriptions test showing students’ abilities include aspects of analyzing, evaluating and creating knowledge.

Based on Figure 1, generally, the percentage of students’ cognitive ability in PBL using manipulative material class is better than the PBL class. PBL supports the improvement of students’ cognitive abilities through concrete representations of abstract problems in mathematics. PBL has given 85.71% on students’ remembering ability, 77.81% on students’ understanding ability, 80.71% on students’ applying ability and 81.75% on students’ creating ability. PBL characteristics such as collaborative learning in small groups, activating prior knowledge through group discussion, having teachers to facilitate learning, and having the resources to help them solve problems given in line with students' cognitive architecture [15,18,28].

PBL instruct students’ to be able to find information, analysis problems and evaluate the problem-solving process given. Collaboration in small groups instructs students’ to be skilled in communication
and form good metacognitive skills [14]. Problem-based learning supports the improvement of students' cognitive abilities.

In addition to problem-based learning, using manipulative materials also supports the improvement of students' cognitive abilities through concrete representations of abstract problems in mathematics. Manipulative materials can help students to translate mathematical abstention concepts into more tangible forms and enable them to connect new knowledge with existing knowledge. Based on Figure 1, this study found that PBL using manipulative material has a positive effect on students' performance of seeing cognitive variables in understanding problems (remembering and understanding), and solving problems (analyzing and evaluating) procedural knowledge and conceptual knowledge. PBL using manipulative materials has given 91.93% on students' remembering ability, 87.09% on students' understanding ability, 84.08% on students' analyzing ability and 69.15% on students' evaluating ability.

Mathematical problems related to the real world applied in student worksheets. As an example, students are asked to find the solution and conclusion about comparing theoretic and experimental probability. The given problem is to determine who has the greatest opportunity for 3 candidates out of 30 students chosen for classroom leader. Student using one red ball as the first candidate, one yellow ball as the second candidate, and one blue ball as the third candidate and take 30 randomly to get the value of experimental probability and compare with the value of theoretical probability to get the conclusion. This mean use of the manipulative material in mathematics learning needs to be accompanied by an understanding of the relationship between the object and the mathematical ideas it describes as stated by Mink [29].

Manipulative materials facilitate students to interpret their mathematical thinking, represent the relationship between mathematical ideas and develop appropriate content for learning mathematics [19,20,30]. The manipulative material is able to develop students' conceptual knowledge, facilitate concrete materials in mathematics, make students’ easily understand and solve problems in their learning. [21,22]. The manipulative material helps students to analyze information about the mathematical concepts they have learned before, with the information they have just obtained to determine a solution to a given problem. Students use manipulative materials to present their work, making it easier for them to re-evaluate the problem-solving process they are doing [31].

4. Conclusion

This study found that PBL uses manipulative materials is more effective than PBL in students’ probability of performance. Implementation of PBL using manipulative materials in mathematics learning provides students the experience to increase their cognitive ability to the model can be applied in the learning process. Real life issues support students to play an active role in the learning process through the use of problems related to their daily lives because these problems will require students to find data, think to design solutions and solve the problem. PBL collaborating students' who work together in small groups. Collaboration provides the motivation to continuously engage in complex tasks and expand opportunities to share inquiry and dialogue and to develop social skills and thinking skills.

PBL using manipulative materials makes the subject teachers more creative and innovative in planning the learning process of mathematics in the classroom. Teachers are required to apply the problems in the real world and relate it with the manipulative materials as symbols of the concept abstracts that exist in the problem.

5. References

[1] Karaali G 2011 PRIMUS vol 21 721
[2] Depdikbud 2016 Peraturan Menteri Pendidikan dan Kebudayaan Nasional Republik Indonesia tentang Standar Proses untuk Satuan Pendidikan Dasar dan Menengah (Jakarta: Depdiknas)
[3] Hofer T and Beckman A 2009 International Journal on Mathematics Education 41 223
[4] Wade C and Tavris C 2015 Invitation to psychology, sixth edition (Upper Saddle River, New
Jersey: Pearson) p. 7
[5] Pritchard D 2010 Synthese 175 133
[6] Pritchard D 2012 Journal of Philosophy 109 247
[7] Carter J A, Jarvis B and Rubin K 2013 Synthese 190 3715
[8] Schunk D H 2012 Learning theories: An educational perspective 6th ed (Upper Saddle River, NJ: Person Educational) p. 454
[9] Kuswana W S 2011 Taksonomi berpikir (Bandung: PT. Remaja Rosdakarya) p. 81
[10] Bloom B S et al 1956 Taxonomy of Educational Objectives: Handbook 1, Cognitive Domain (New York: David McKay) p. 2-19
[11] Anderson L W and Krathwohl D R 2001 A taxonomy for learning, teaching, and assessing: a revision for Bloom’s taxonomy of educational objectives (New York: Addison Wesley Logman, Inc) p. 45-86
[12] De Bock D et al 2011 Journal for research in mathematics education 42 109
[13] Tan O S 2003 Problem based learning innovation: using problem to power learning in the 21st century (Shenton Way, Singapore: Cengage Learning) p. 22
[14] Goodman R J B 2010 J Econ Finan 34 477
[15] Bayat S and Tarmizi R A 2012 Procedia - Social and Behavioral Sciences 46 3146
[16] DeYoung C G, Flanders J L and Peterson J B 2008 Creativity Research Journal 20 278
[17] Chuan-Li H 2011 Proceedings of the British Society for Research into Learning Mathematics vol. 31
[18] Rochani S and Abadi A M 2015 Jurnal Riset Pendidikan Matematika 3 273
[19] Posamentier A S, Smith B S and Stepelman J 2010 Teaching secondary mathematics: teaching and enrichment unit. (8th ed) (Boston, MA: Allyn & Bacon) p. 6
[20] Cope L 2015 Delta Journal of Education 5 10
[21] Belenky D M and Nokes T J 2009 The Journal of Problem Solving 2 102
[22] Sulistyaningsih D. et. al. 2017 Journal of Physics: Conf. Series. 824.
[23] Gaetano J 2014 The effectiveness of using manipulatives to teach fractions Theses and Dissertations 495 http://rdw.rowan.edu/etd/495
[24] Haoalder F A, Ali R and Foysol K 2015 Research in vocational and training 2 99
[25] Nitko A J and Brookhart S M 2011 Educational Assessment of Students (6th ed) (Boston, MA: Pearson Education, Inc.) p. 301-304
[26] Ebel R L and Frisbie D A 1991 Essentials Of Educational Measurement (India: Prentice Hall) p. 232
[27] Allen M J and Yen W M 1979 Introduction to measurement theory (Monterey: Brooks/Cole) p. 83-84
[28] Bayat S and Tarmizi R A 2012 Procedia - Social and Behavioral Sciences 46 3146
[29] Mink D V 2010 Strategies for teaching mathematics. (Huntington Beach, CA: Shell Education p. 71
[30] Moyer P S 2001 Educational Studies in Mathematics 47 175
[31] Sarama J and Clements J D 2009) Child Development Perspectives: Society for Research in Child Development. 3 145