Journal of Mathematics and Science Teacher
2022, 2(2), em017
e-ISSN: 2752-6054
https://www.mathsciteacher.com/

MODESTUM

Research Article **OPEN ACCESS**

Critical thinking skill through problem-based learning with problem posing within-solution

Ni Made Intan Kertiyani [1,2]*, Siti Fatimah [2], Jarnawi Afgani Dahlan [2]

[1] University of Mataram, Nusa Tenggara Barat, INDONESIA
[2] Universitas Pendidikan Indonesia, Jawa Barat, INDONESIA
***Corresponding Author:** intan@unram.ac.id

Citation: Kertiyani, N. M. I., Fatimah, S., & Dahlan, J. A. (2022). Critical thinking skill through problem-based learning with problem posing within-solution. *Journal of Mathematics and Science Teacher, 2*(2), em017. https://doi.org/10.29333/mathsciteacher/12369

ARTICLE INFO

Received: 27 Jun. 2022

Accepted: 08 Aug. 2022

ABSTRACT

Problem-based learning (PBL) is considered to improve students' critical thinking (CT) skills. However, there are several obstacles to implementing this instructional model. PBL is highly time-consuming and creates a high cognitive load, so it is not suitable for all students, especially students with low prior knowledge. To investigate this problem, we conducted a quasi-experiment to study the difference in the improvement of CT skills between students who study using PBL and student who study using PBL with problem posing within-solution (PPWS). The sample of this research is 71 high school students in Mataram City. The result revealed that there was no difference in the enhancement of CT skill between students who learn using PBL and student who learn using PBL with PPWS. This means we can substitute PBL into PBL with PPWS to foster student CT skills.

Keywords: problem-based learning, problem posing, critical thinking, innovation, within solution

INTRODUCTION

Problem-Based Learning

Problem-based learning (PBL) has advantages that are believed to improve critical thinking (CT) skills (Masek, 2011; Mulyanto et al., 2018; Saputra et al., 2019; Wee, 2004; Weissinger, 2003;). However, there are several obstacles when implementing PBL. One of the obstacles is the lack of time (Burris & Garton, 2007). Due to short teaching hours, there were unfavorable opinions regarding the availability of time for the use of PBL in the classroom (Mohammed, 2015). Nurlaily et al. (2019) explained when guiding both individual and group investigation, teacher must direct the process of group discussion because the students are not used to building knowledge based on the provided problem on the worksheet. This causing the discussion time in group become more limited. Meanwhile, learners required sufficient time in class to analyze the mathematical issue in order to learn the topic (Al Said et al., 2019).

When undertaking PBL, the workload also contributed to the lack of time. Students who were new to PBL felt unsure of their role in the learning process, what was expected of them, and which component of the problem they should concentrate on (Hung, 2011). As a result, unproductive investigation and learning of the topic occurred, such as spending too much time researching minor problems (Lieux, 2001).

Student prior knowledge also influence the effectiveness of PBL (Wilder, 2014). Borhana and Yasin (2013) revealed that students still have difficulty setting strategies for solving initial problems at the beginning of implementing PBL. Actually, the initial problem given in PBL help students activate any formal or informal knowledge they may have about the topic (Schmidt et al., 2007). However, students with low prior knowledge cause most of the learning activities had been focused on coaching them to understand the problem, so the learning process was slowed (Jailani et al., 2017). Peters (2015) also agree that from cognitive load theory, if learners do not have the basic mathematical knowledge to support the problem-solving process, they will find it incredibly difficult to participate, resulting in minimal advantage from the learning environment.

Another problem found in implementing PBL is student mindset and habits especially from students who are on transition from traditional learning to PBL (Hung, 2011). They need to shift their habits from study passively to actively and also take responsibility on what need to investigate. It will be very difficult to expect them to change their mindset and habits in short time (Hung 2006).

This work was derived from the master's thesis of the corresponding author.

Problem-Based Learning with Problem Posing within-Solution

According to some research, there are problems in implementing PBL, namely lack of time, workload, student prior knowledge and student mindset. Based on these obstacles found in implementing PBL, we integrated PBL with problem posing within-solution (PPWS). PPWS is the submission of sub-questions to make it easier to solve the main problem (Silver & Cai, 1996).

PBL steps consists of

(1) exposing the student to the problem,

(2) arranging the student to learn,

(3) guiding the students to perform do investigations alone and in groups,

(4) designing and presenting the problem-solving procedures, and

(5) critically evaluating the problem-solving process (Arends & Kilcher, 2012).

Problem-based learning with problem posing within-solution (PBLPPWS) differ in third step. In third step, PBL involves students to deconstructing the question themselves. Meanwhile in PBLPPWS, teacher guiding students individual and group investigation using problem posing within solution by giving several small questions in student worksheet.

By breaking down the questions into several small questions, we reduced student task to a level deemed achievable. Simons and Ertmer (2005) found that this way can provide appropriate scaffolding which can enhance learner ability. Each student can share the task of solving sub-questions so that they can shorten the time to solve the questions. In addition to shortening the time, Mayer and Chandler (Chinnappan & Chandler, 2010) added that solving problems into several sub-questions can also reduce the cognitive load of the problem.

METHODS

This study was a quasi-experiment with a control group pre- and post-test design, which was conducted in one of the senior high schools in Mataram City. The samples were 71 students of grade XI in that school. The experiment group consisted of 35 students who study using PBLPPWS and the control group consisted of 36 students who study using PBL. The control group studied using PBL whose syntaxes are

(1) students are introduced to the problem,

(2) teacher organizing the student to learn,

(3) students do independent and group investigations with teacher guiding,

(4) students creating and presenting the problem-solving procedures, and

(5) teacher assessing the problem-solving process critically.

Furthermore, experiment group studied using PBLPPWS whose steps are

(1) students are introduced to the problem,

(2) teacher organizes students to learn,

(3) teacher guides individual and group investigation using PPWS,

(4) student presenting work, and

(5) teacher analyzes and evaluates the work of students.

Before student study using PBL and PBLPPWS, they answer the pre-test given by researcher. After that, student studied using PBL for controlled group and PBLPPWS for experimental group. In this experiment, the problem topic is derivative. There are four subtopics of derivative, as follows:

(1) concave up and down function,

(2) maximum and minimum value,

(3) application of derivative as velocity, and

(4) applying maximum and minimum value in daily life problem.

These four topics are discussed in six meetings according to allocation time from school. After six meetings, the student completed the post-test. The syntaxes of this experiment are presented in **Figure 1**.

The instrument which used in this research was the CT ability test to measure student CT ability. The test consists of three questions. Each question measure following indicators is explained in **Table 1**. We also conduct some interview to confirm the student answer in pre- and post-test.

After post-test, the data of CT ability was analyzed quantitatively using statistic test and qualitatively to describe the data obtained. Before applying statistic test, we test the normality and homogenity of data. For the normality test, we use the Shapiro-Wilk (Mendes & Pala, 2003). Meanwhile, the homogeneity of test was analyzed using Levene statistic test (Rice University, 2016). If the normality and homogeneity data are met, we compare the enhancement of student CT ability using t-test (Coladarci, 2011). If one of those two assumptions were not met, we compare the enhancement of student CT ability using U-Mann Whitney test (King et al., 2011). The enhancement of student CT ability or n-gain was calculated using formula

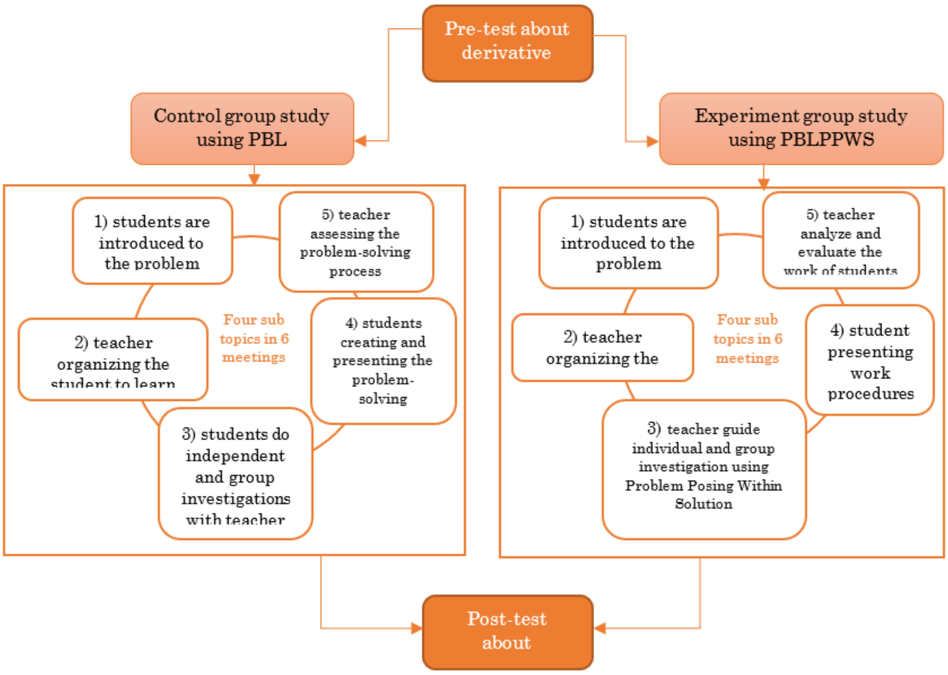

Figure 1. The syntaxes of experiment

Table 1. Indicators of each problem in critical thinking ability test

Problem	Indicators
Problem 1	Checking the truth of statement and answer with reason
Problem 2	Ask relevant question
Problem 3	Identify relevant and irrelevant data

Table 2. n-gain of student critical thinking skill level

n-gain score	Level
g>0.7	High
0.3<g≤0.7	Medium
g≤0.3	Low

Table 3. The data of mathematical critical thinking skill

	PBLPPWS	PBL
The average of pre-test score	1.96	1.85
The average of post-test score	14.79	14.10
The average of student critical thinking ability n-gain	0.38	0.36
The level of student critical thinking ability n-gain	Medium	Medium
The ideal maximal score: 36		

$$n - gain = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score}.$$

The classification of n-gain from Hake (Meltzer, 2002) depicted in **Table 2**.

Ethics

Regarding some ethical issues in this study such as ethical issues in research objectives, in collecting data, and in writing and publishing research results, the subject's weaknesses and strengths were presented objectively. Moreover, both the school and the teacher knew the purpose of this study. During and after the research process there are no activities that endanger the participants. The publication of the results of this study is intended for academic purposes and is limited to the academic environment to prevent data misuse.

RESULT AND DISCUSSION

The data of mathematical CT skill are obtained from pre-test, post-test, and interview to confirm the answer of the student. The result can be shown in **Table 3**.

Table 4. The result of Shapiro Wilk test

Type of class	Sig.
PBLPPWS	0.280
PBL	0.367

As depicted in **Table 3**, the average of pre-test, post-test, and student CT ability n-gain are relatively in small gap. According to post-test score, the score of students with PBLPPWS and PBL were less than 50% of ideal maximal score. It means the achievement of student CT still low. Meanwhile, the level of student CT ability for PBLPPWS and PBL are both in the medium level.

Before analyzed the n-gain of CT ability, we run the Shapiro-Wilk test to check the normality of n-gain data. **Table 4** shows the result of Shapiro-Wilk test.

According to **Table 4**, the significance of PBLPPWS is 0.280 and the significance of PBL is 0.367. Significancy are more than significance alpha=0.05. It means $\mathbf{H_o}$ is accepted; both n-gain from PBLPPWS and PBL class come from normally distributed population. Furthermore, we also run test of homogeneity variances using Levene statistic test. From that test, the significance of n-gain is 0.517. This significance is more than significance alpha. The conclusion is the PBLPPWS class and PBL class have the same variances. Since the n-gain met the normality and homogeneity, we continue the statistic test to the t-test.

The significance (2-tailed) from t-test was 0.671. This significance was more than the significance alpha=0.05. It means there are no difference n-gain from the PBLPPWS group and PBL group. We conclude that the student who learnt using PBLPPWS has no significantly different CT ability enhancement to student who learnt using PBL.

The result showed that there was no difference in the CT skill between students who learn using PBL and student who learn using PBLPPWS. This may be caused by several things, namely trigger events and metacognitive questions given by the teacher. The first cause is students' trigger events. When thinking critically, someone will experience five stages, namely trigger event, appraisal, exploration, developing alternative perspective, and integration (Brookfield in Murphy, 2004). The first stage is the trigger events. These are the stages when students begin to think critically. In PBL, the main problem given by the teacher at the beginning of the lesson becomes a planned trigger event. Then, other trigger events occur unplanned during the process of solving the main problem. Meanwhile, in PBLPPWS, the main problem and the sub-questions given by the teacher become planned trigger events. PBLPPWS students also tended to experience other unplanned trigger events when students investigate the answer to every sub-question. The existence of unplanned trigger events both in the PBL and PBLPPWS groups probably cause no difference in the improvement of CT skill ability between these groups.

The second cause is metacognitive questions given by the teacher to help student difficulties. In the PBL group, the teacher guides this group with metacognitive questions to help students' difficulties. Meanwhile, in the PBLPPWS group, when students feel confused about answering the sub-questions, the teacher also guides them with metacognitive questions. Wee (2004) explains that metacognitive questions can improve students' ability to argue. In addition, these questions also trigger activities such as debating during group discussion, teaching other group members, and sharing information which stimulates the development of CT skills (Schmidt, 1993). The metacognitive question which was given by the teacher also stimulates students to think freely, which is characteristic of critical thinkers (Birgili, 2015).

CONCLUSION

This result showed that there was no difference in enhancement of CT skill between students who learn using PBL and students who learn using PBLPPWS. This means we can substitute PBL to PBLPPWS to improve students' CT skills. For future work, we wonder what results would have been obtained if the sample were junior high school students.

Author contributions: NMIK: carried out background, design, research instrument of the study, did the experiment at the school, performed data analysis, and drafted the manuscript; **SF:** participated in approved the background study, approved research instrument, and interpreting the result of analysis data; & **JAD:** helped in design of the study, approved the research instrument, and interpreting the data analysis. All authors have agreed with the results and conclusions.

Funding: This study was supported by the Grant from Indonesia Endowment Fund for Education (LPDP) number PRJ.2161 /LPDP.3/2016. The opinions expressed are those of the researcher and do not necessarily represent the views of LPDP.

Acknowledgements: The authors would like to thank to the school staffs and teacher for assistance and to the students who participated in this study.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Al Said, R. S., Du, X., ALKhatib, H. A. H., Romanowski, M. H., & Barham, A. I. I. (2019). Math teachers' beliefs, practices, and belief change in implementing problem-based learning in Qatari primary governmental school. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(5), 1-14. https://doi.org/10.29333/ejmste/105849

Arends, R. I., & Kilcher, A. (2010). *Teaching for students learning: Becoming an accomplished teacher*. Taylor & Francis. https://doi.org/10.4324/9780203866771

Birgili, B. (2015). Creative and critical thinking skills in problem-based learning environments. *Journal of Gifted Education and Creativity, 2*(2), 71-80. https://doi.org/10.18200/JGEDC.2015214253

Borhana, M. T., & Yassin, S. M. (2013). Implementation of problem-based learning (PBL)–in a malaysian teacher education course: Issues and benefits from students' perspective. In *Proceedings of the 4th international research symposium on problem-based learning* (pp. 181-190).

Burris, S., & Garton, B. (2007). Effect of instructional on critical thinking and content knowledge: Using problem-based learning in the secondary classroom. *Journal of Agricultural Education, 48*(1), 106-116. https://doi.org/10.5032/jae.2007.01106

Chinnappan, M., & Chandler, P. A. (2010). Managing cognitive load in the mathematics classroom. *Australian Mathematics Teacher, 66*(1), 5-11. https://search.informit.org/doi/10.3316/informit.961020792951417

Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. Interdisciplinary. *Journal of Problem-Based Learning, 1*(1), 55-77. https://doi.org/10.7771/1541-5015.1006

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development, 59*, 529-552. https://doi.org/10.1007/s11423-011-9198-1

Jailani, J., Sugiman, S., & Apino, E. (2017). Implementing the problem-based learning in order to improve the students' HOTS and characters. *Jurnal Riset Pendidikan Matematika* [*Journal of Mathematics Education Research*], *4*(2), 247-259. https://doi.org/10.21831/jrpm.v4i2.17674

King, B. M., Rosopa, J. P, & Minium E. W. (2011). *Statistical reasoning in the behavioral sciences*. John Wiley & Sons, Inc.

Lieux, E. M. (2001). A skeptic's look at PBL. In B. Duch, S. E. Groh, & D. E. Allen (Eds.), *The power of problem-based learning: A practical "how to" for teaching undergraduate courses in any discipline*. Stylus Publishing.

Masek, A. (2011). The effect of problem-based learning on critical thinking ability: A theoretical and empirical review. *International Review of Sciences and Humanities, 2*(1), 215-221.

Mendes, M., & Pala, A. (2003). Type I error rate and power of three normality tests. *Pakistan Journal of Information and Technology*, *2*(2), 135-139. https://doi.org/10.3923/itj.2003.135.139

Mohammed, M. E. S. (2015). An investigation into pre-service teachers' perceptions of learning primary school science using the method of problem-based learning (PBL). *World Journal of Education*, *5*(3), 44-60. https://doi.org/10.5430/wje.v5n3p44

Mulyanto, H., Gunarhadi, G., & Indriayu, M. (2018). The effect of problem-based learning model on student mathematics learning outcomes viewed from critical thinking skills. *International Journal of Educational Research Review*, *3*(2), 37-45. https://doi.org/10.24331/ijere.408454

Nurlaily, V. A., Soegiyanto, H., & Usodo, B. (2019). Elementary school teachers' obstacles in the implementation of problem-based learning model in mathematics learning. *Journal on Mathematics Education*, *10*(2), 229-238. https://doi.org/10.22342/jme.10.2.5386.229-238

Peters, M. (2015). Using cognitive load theory to interpret student difficulties with a problem-based learning approach to engineering education: A case study. *Teaching Mathematics and its Applications: An International Journal of the IMA*, *34*(1), 53-62. https://doi.org/10.1093/teamat/hru031

Rice University. (2016). *Introductory statistics*. Open Stax.

Saputra, M. D., Joyoatmojo, S., Wardani, D. K., & Sangka, K. B. (2019). Developing critical-thinking skills through the collaboration of jigsaw model with problem-based learning model. *International Journal of Instruction*, *12*(1), 1077-1094. https://doi.org/10.29333/iji.2019.12169a

Schmidt, H. G., Loyens, S. M., Van Gog, T., & Paas, F. (2007). Problem-based learning is compatible with human cognitive architecture: Commentary on Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 91-97. https://doi.org/10.1080/00461520701263350

Schmidt, H.G. (1993). Foundations of problem-based learning: Some explanatory notes. *Medical Education*, *27*, 422-432. https://doi.org/10.1111/j.1365-2923.1993.tb00296.x

Silver, E. A., & Cai, J. (1996). An analysis of aritmatic problem posing by middle school students. *Journal for Research in Mathematics Education, 27* (5), 521-539. https://doi.org/10.2307/749846

Simons, K. D., & Ertmer, P. A. (2005). Scaffolding disciplined inquiry in problem-based environments. *International Journal of Learning, 12*(6), 297-305. https://doi.org/10.18848/1447-9494/CGP/v12i06/47900

Wee, K. N. L. (2004). *Jump start authentic problem-based learning*. Pearson.

Weissinger, P. A. (2003). *Critical thinking skills of first year denial student enrolled in a hybrid curricuum with a problem-based learning component* [Doctoral dissertation, Indiana University, Bloomington].

Wilder, S. (2014). Impact of problem-based learning on academic achievement in high school: A systematic review. *Educational Review, 67*(4), 1-21. https://doi.org/10.1080/00131911.2014.974511