The effect of Double Loop Problem Solving (DLPS) on critical thinking skills and mathematical problem solving abilities

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Abstract. This research aimed to identify the effect of DLPS model on students' critical thinking skills and mathematical problem-solving abilities. The variables involved in this research were thinking skills and mathematical problem-solving abilities as independent variables, and DLPS model as a dependent variable. One of the best learning strategies to encourage active thinking and problem-solving is the Double Loop Problem Solving (DLPS) model. DPLS model is a learning model of mathematical problem-solving approach that emphasizes students to find the main cause of the existence of a problem. This is in line with students' mathematical problem-solving abilities that require the student to understand problems, plan or design problem-solving strategies, carry out calculations and verify the truth of the outcome or solution.

The population of this study was the students at seventh grade in Junior High School State 1 Rembang, Purbalingga Regency, even semester in the school year 2017/2018. There was selected seventh grade of class B as experimental with 34 students and seventh grade of class E as control class with 34 students. The summary of the hypothesis testing, with the help of the SPSS program, is presented. Using Kolmogorov-Smirnov test for normality test and Levene's test for equality of variances for homogeneity test, obtained significant value are 0.057; 0.145 and 0.168; 0.062 0.063; 0.681 and 0.244; 0.171 and 1.306; 2.359 more than alpha 0.05. It means that the students' critical thinking skills and mathematical problem-solving abilities fulfilled assumption of normality test and homogeneity test. After conducting a series of normality and homogeneity tests, it was concluded that t-test for equality of means was used for hypothesis testing. The significant value is 0.019; 0.012 less than alpha 0.05. So that H0 is rejected, it means that students' critical thinking skills and mathematical problem-solving ability taught by using DLPS model are better than students' critical thinking skills and mathematical problem-solving ability taught by conventional learning. In other words, the DLPS model influences or effects on students' critical thinking skills and mathematical problem-solving abilities.

1. Introduction
Mathematics is a subject that has an important role in human life. Any problem that occurs in everyday life definitely requires mathematics as one way to solve it. Mathematics learning is the process of interaction between teachers and students in a learning environment in order to acquire knowledge and mathematics abilities [1]. The 2013 curriculum in Indonesia is designed to direct students to understand their potentials, interests, and talents for career development both in higher education and in community careers. Students are required to be active in the learning process and have character qualities correspond to 21st-century skills [2]. Students are subjects who have the ability to seek actively, process, construct,
and apply knowledge in daily life. In order to deeply understand and apply knowledge, students need to be encouraged to work to solve problems, find everything for themselves, and strive to realize their ideas [3].

One of the ultimate skills needed in 21st-century learning is critical thinking skills. Critical thinking skills (CTS), one part of higher-order thinking skills, has various definitions [4]. CTS as logical-reflexive thinking emphasized on the logic, reflection, and the process of making decisions [5]. Almost similar, define CTS as certain assessment with certain purposes generated through steps of interpretation, analysis, evaluation, and taking conclusion [6]. In the practice, CTS involves various skills such as identifying the source of information, analyzing the credibility, reflecting the information and taking the conclusion [7]. Although the definition of CTS is varied, however, the most important factor is that students must own the skills to learn for a lifetime critically.

CTS is frequently made as the basis to understand the proof, issue, and taking a conclusion. Nowadays, the development of CTS becomes the main purpose of science learning at tertiary level. However, It showed that students' CTS is at a low level the empirical study in Indonesia conducted [8-11]. Reports the lack of students' CTS can be seen from their inability in giving arguments properly, giving less logical assumption, and giving a little evaluation based on the relevant facts [10]. They also agree that the low level of students' CTS skills is caused by lecturer-centered learning, the lecturer at the front and the students listen; in other words, the interaction is only one way. It indicates that lecturer still has homework on how to teach science effectively and create interactive learning environments.

Besides CTS, problem-solving skills are also important skills in teaching and learning at higher education. Problem-solving is defined as formulating the new answer to create a solution, in which each step is the pioneer of the next step and the result of the previous step [12]. We contend that students' skills will increase if they are involved in problem-solving and succeed in finding the solution. The problem that can improve students' problem-solving skills is the problem that enables them to analyze, synthesize, and evaluate [13]. Therefore, the purpose of the science learning nowadays is not only about transferring knowledge and skills, but also facilitating both of them and use the new knowledge to make the decision and solve the problem [14,15]. Mathematical problem-solving abilities (MPSA) need to be developed because these skills are necessary to solve problems in everyday life and survival in the future. As one of the mathematical abilities, MPSA consists of four activities: (1) understanding the problem, which consists of identifying the known data, identifying the required data, checking the data and compiling the problem to mathematical models; (2) choosing strategy and executing strategy; (3) performing calculations or solving mathematical models; (4) Interpreting the solution (outcome) to the original problem and checking the correctness of the solution [16].

One of the best learning strategies to encourage active thinking and problem-solving is the Double Loop Problem Solving (DLPS) model. DLPS model is a learning model of mathematical problem-solving approach that emphasizes students to find the main cause of the existence of a problem. This is in line with students' mathematical problem-solving abilities that require the student to understand problems, plan or design problem-solving strategies, carry out calculations and verify the truth of the outcome or solution. The application of the model in learning encourages students to be able to understand, interpret and evaluate mathematical ideas in writing. DLPS model invites students to be active in learning. This model focuses on the complex and unstructured troubleshooting [17]. In this model, students are encouraged to work on two different problems loops but both of them are related.

The steps of the double loop problem-solving learning model as follows [18]: (1) Identify the problem, not just the symptoms. At this stage, detection includes everything that is a factor of the problem to be solved. (2) Detect immediate causes and rapidly implement temporary solutions. These direct causes are more obvious, therefore easy to detect and can be searched for solutions to be applied quickly. (3) Evaluate the success of a temporary solution. At this stage, an evaluation of the effectiveness and success of existing temporary solutions has been implemented. (4) Decide whether root problem analysis is required or not. At this step, students decided to perform a root cause analysis or sufficient up to this point, taking into account the results of previous evaluations. (5) If needed, the detection of the cause of the higher-level problem is made. The higher-searched cause is higher than the cause that
has been found previously. (6) Designing the root solution to the problem. The designed solution is certainly not a temporary solution anymore, but a solution that can solve the problem thoroughly.

Previous research showed that experimental class that used DLPS model can get a higher average of a gain score higher than control class and it can conclude that the use of DLPS model gives significant effects against student learning outcome especially in spatial thinking ability [19]. Research that conducted by Roliyani showed that using DLPS model can improve students learning outcome as evidenced by an increase of 70% in cycle I and 80% in cycle II [20]. The success of the DLPS model in influencing and improving learning outcomes based on previous research encourages researchers to know the effect of DLPS model on students who take entomology courses in of Biology Education Department Faculty Teacher Training and Education, Mulawarman University. Based on the description of the background described, the purpose of this study was to determine whether Double Loop Problem Solving had effects on students' critical thinking abilities and mathematical problem-solving abilities.

2. Method
This study was quasi-experimental research that used a nonequivalent posttest-only control group design where aimed to compare the influence of uses DLPS model and the conventional (model on the students' critical thinking skills. Likewise, the DLPS model and the conventional (direct instruction learning) model on the students' mathematical problem-solving abilities. The variables involved in this research were thinking skills and mathematical problem-solving abilities as the independent variable, and DLPS model as the dependent variable. Research design can be seen in Table 1.

Table 1. Research design.

| Class          | Treatment | Test |
|----------------|-----------|------|
| Experimental   | X         | T    |
| Control        | -         | T    |

Table 1 shows that the treatment given in the experimental class (X mark) where the researchers applied the DLPS model in the learning, while in the control class, the researchers did not apply the DLPS model in learning but applied conventional learning. Both of them given post-test (T mark). The population of this study was the students at seventh grade in Junior High School State 1 Rembang, Purbalingga Regency, even semester in the school year 2017/2018. There are 5 with a total of 172 students. The sampling technique used in this study is Cluster Random Sampling which is selected by lottery. Cluster Random Sampling is a technique used to select the sample of randomizing groups if the sample of the randomized groups (classes) from the population have homogeneous characteristics. It means there is no superior class [21]. There was selected seventh grade of class B as experimental with 34 students and seventh grade of class E as control class with 34 students.

The data of the research were collected using test. This test is used to measure students' critical thinking skills and mathematical problem-solving abilities. Furthermore, the data were analyzed by using t-test after conducting a series of normality and homogeneity tests.

3. Result and discussion
Based on the posttest results of critical thinking skills and mathematical problem-solving abilities obtained a series of normality and homogeneity tests as follows:

Table 2. The descriptive statistics of the post-test students' critical thinking skills on experimental class and control class.

| Descriptive Statistics | Experimental Class | Control Class |
|------------------------|--------------------|---------------|
| N                      | 34                 | 34            |
| Max                    | 88                 | 88            |
| Min                    | 44                 | 25            |
| Average                | 71.79              | 64.65         |
From table 2, it can be seen clearly that the average score of the experimental class is higher than the average score of the control class. The average score of the experimental class is 71.79 and the average score of the control class is 64.65. Moreover, the maximum and the minimum scores for the experimental class is higher than the control class. It means that overall the test results of students' critical thinking skills on the experimental class was better than the control class.

Table 3. The descriptive statistics of the post-test students' mathematical problem solving abilities on experimental class and control class.

| Descriptive Statistics | Experimental Class | Control Class |
|------------------------|--------------------|--------------|
| N                      | 34                 | 34           |
| Max                    | 94                 | 86           |
| Min                    | 58                 | 48           |
| Average                | 74.24              | 68.59        |

From table 3, it can be seen clearly that the average score of the experimental class is higher than the average score of the control class. The average score of the experimental class is 74.24 and the average score of the control class is 68.59. Moreover, the maximum and the minimum scores for the experimental class is higher than the control class. It means that overall the test results of students' mathematical problem-solving abilities on the experimental class were better than the control class. Based on table 2 and table 3 show that the descriptive statistics on the experimental class were better than the control class.

Table 4. Normality test of the post-test students' critical thinking skills on experimental class and control class.

| Class  | Kolmogorov-Smirnov | Shapiro-Wilks |
|--------|--------------------|---------------|
|        | Statistic | Df | Sig. | Statistic | Df | Sig. |
|         | Experimental | 0.148 | 34 | 0.057 | 0.940 | 34 | 0.063 |
|         | Control     | 0.129 | 34 | 0.168 | 0.960 | 34 | 0.244 |

Table 5. Normality test of the post-test students' mathematical problem solving abilities on experimental class and control class.

| Class  | Kolmogorov-Smirnov | Shapiro-Wilks |
|--------|--------------------|---------------|
|        | Statistic | Df | Sig. | Statistic | Df | Sig. |
|         | Experimental | 0.131 | 34 | 0.145 | 0.977 | 34 | 0.681 |
|         | Control     | 0.146 | 34 | 0.062 | 0.955 | 34 | 0.171 |

From table 4 and 5, it can be seen clearly that significant value for the experimental class and the control class were 0.057; 0.145 and 0.168; 0.062 more than alpha 0.05 respectively, based on Kolmogorov-Smirnov test. Moreover, the significant value for the experimental class and the control class were 0.063; 0.681 and 0.244; 0.171 more than alpha 0.05 respectively, based on the Shapiro-Wilks test. It means that both the experimental class and the control class fulfilled assumption of normality test for students' critical thinking skills and mathematical problem-solving abilities.
Table 6. Independent sample t-test of the post-test students' critical thinking skills.

| Levene's Test for Equality of Variances | t-test for Equality of Means | 95% Confidence Interval of the Difference |
|----------------------------------------|-----------------------------|--------------------------------------|
|                                        | F   | Sig. | T   | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower  | Upper  |
| Equal variances assumed                | 1.306 | 0.257 | 2.407 | 66 | 0.019 | 7.147 | 2.969 | 1.220 | 13.075 |
| Equal variances not assumed            | 2.407 | 62.218 | 0.019 | 7.147 | 2.969 | 1.213 | 13.081 |

Table 7. Independent sample t-test of the post-test students' mathematical problem solving abilities.

| Levene's Test for Equality of Variances | t-test for Equality of Means | 95% Confidence Interval of the Difference |
|----------------------------------------|-----------------------------|--------------------------------------|
|                                        | F   | Sig. | T   | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower  | Upper  |
| Equal variances assumed                | 2.359 | 0.129 | 2.592 | 66 | 0.012 | 5.647 | 2.969 | 1.298 | 9.996 |
| Equal variances not assumed            | 2.592 | 62.218 | 0.012 | 5.647 | 2.969 | 1.298 | 10.001 |

The summary of the hypothesis testing, with the help of the SPSS program, is presented from table 6 and 7. Using Levene's test for equality of variances obtained significant value are 1.306; 2.359 more than alpha 0.05. It means that the students' critical thinking skills and mathematical problem-solving abilities fulfilled assumption of homogeneity test.

After conducting a series of normality and homogeneity tests, it was concluded that t-test for equality of means was used for hypothesis testing. From table 6 and 7, it can be seen clearly that the significant value 0.019; 0.012 less than alpha 0.05. So that H0 is rejected, it means that students' critical thinking skills and mathematical problem-solving ability taught by using DLPS model are better than students' critical thinking skills and mathematical problem-solving ability taught by conventional learning. In other words, the DLPS model influences or effects on students' critical thinking skills and mathematical problem-solving abilities.

This research can be used for the teacher as an alternative learning model to improve students' critical thinking skills and mathematical problem-solving abilities in the class. From the next future research, it can determine whether the DLPS model will have an effect on students' mathematical High Order Thinking Skills (HOTS).

4. Conclusion
Based on the results of research conducted at student's seventh grade in Junior High School State 1 Rembang, Purbalingga Regency, it can be concluded that students' critical thinking skills and mathematical problem-solving ability taught by using DLPS model are better than students' critical thinking skills and mathematical problem-solving ability taught by conventional learning. In other words, the DLPS model influences or effects on students' critical thinking skills and mathematical problem-solving abilities.

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References
[1] Kurniadi G and Purwaningrum J P 2018 Double Loop Problem Solving Learning Model on Statistical Material at MTS NU Nahdlatul Atfhal Kudus Int. Semin. Educ. Dev. Asia 195–9
[2] Sutama, Suyatmini, Sutopo A, Prayitno H J and Anif S 2019 Communication Skill of Junior High School Students in Mathematics Learning based on Double Loop Learning Int. J. Innov. Sci. Res. Technol. 4 332–7
[3] Sutama S, Narimo S and Haryoto H 2012 Mathematics Learning Management at Elementary School Post Merapi Eruption Int. J. Educ. 4 192–203
[4] Irwanto I, Saputro A D, Rohaeti E and Prodjosantoso A K 2018 Promoting Critical Thinking and Problem Solving Skills of Preservice Elementary Teachers through Process-Oriented Guided-Inquiry Learning (POGIL) Int. J. Instr. 11 777–94
[5] Ennis R H 1996 Critical Thinking Dispositions: Their Nature and Assessability Informal Log. 18
[6] Shin H, Ma H, Park J, Ji E S and Kim D H 2015 The Effect of Simulation Courseware on Critical Thinking in Undergraduate Nursing Students: Multi-Site Pre-Post Study Nurse Educ. Today 35 537–42
[7] Linn M C 2000 Designing the Knowledge Integration Environment Int. J. Sci. Educ. 22 781–96
[8] Fuad N M, Zubaidah S, Mahanal S and Suarsini E 2017 Improving Junior High Schools’ Critical Thinking Skills Based on Test Three Different Models of Learning Int. J. Instr. 10 101–16
[9] Husamah H, Fatmawati D and Setyawan D 2018 OIDDE Learning Model: Improving Higher Order Thinking Skills of Biology Teacher Candidates Int. J. Instr. 11 249–64
[10] Muhlisin A, Susilo H, Amin M and Rohman F 2016 Improving Critical Thinking Skills of College Students through RMS Model for Learning Basic Concepts in Science. Asia-Pacific Forum Sci. Learn. Teach. 17
[11] Suardana I N, Redhana I W, Sudiatmika A A I A R and Selamat I N 2018 Students’ Critical Thinking Skills in Chemistry Learning Using Local Culture-Based 7E Learning Cycle Model Int. J. Instr. 11 399–412
[12] Çalışkan S, Selçuk G and Erol M 2010 Instruction of problem solving strategies: Effects on physics achievement and self-efficacy beliefs J. Balt. Sci. Educ. 9
[13] Ültay E 2017 Examination of context-based problem-solving abilities of pre-service physics teachers J. Balt. Sci. Educ. 16 113–22
[14] Irwanto, Rohaeti E and Prodjosantoso A K 2018 Undergraduate students’ science process skills in terms of some variables: A perspective from Indonesia J. Balt. Sci. Educ. 17 751–64
[15] Shieh R-S and Chang W 2014 Fostering student’s creative and problem-solving skills through a hands-on activity J. Balt. Sci. Educ. 13 650–661
[16] Hendriana H, Rohaeti E E and Sumarmo U 2017 Hard skills dan soft skills matematik siswa
[17] Mas’ad M, Nizaar M and Putra A M 2016 The Effect of Double Problem Solving Learning Method on Students’ IPS Learning Outcomes Class VIII SMP Negeri 3 Mataram Lesson Year 2015-2016 Paedagoria 7 73
[18] Pradipta S G, Mahfu H and Atmojo I R W 2014 Application of DLPS (Double Loop Problem Solving) Learning Model to Improve The Understanding of The Concept of The Effect of Physical Environment on Land J. Syst. 4
[19] Umeyaroh F and Handoyo B 2017 The Influence of Double Loop Problem Solving Learning Models to Senior High School Learners Spatial Thinking Ability Int. Interdiscip. J. Sch. Res. 3
[20] Roliyani 2016 Efforts to Improve Student Learning Outcomes Through the Use of Learning Models Double Loop Problem Solving J. PENEDUKASI 3 560–6
[21] Lestari K E and Yudhanegara M R 2015 Penelitian pendidikan matematika