

The Influence of Problem Based Learning on Critical Thinking Ability for Students in Optical Instrument Topic

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ABSTRACT

The research aims to reveal the influence of the Problem Based Learning (PBL) model on students' critical thinking ability in optical instrument material. This research is a quasi-experimental research with Pre-test and Post-test Design. The subjects of this study were class X MAN 3 Malang. The experimental and control classes received PBL models and conventional learning models respectively. The instrument of this study was the Optical Instrument Critical Thinking Ability Test in the form of 14 essay questions with Cronbach's alpha reliability 0.78. The research data were analyzed using several tests including t-test, N-gain, and size effect tests. Based on the results of the analysis, it was shown that the implementation of the PBL model succeeded in increasing students' critical thinking ability higher than that of conventional learning. The experimental class was able to reach the high N-gain score category, while the control class was in the medium category. The research has a "large" size effect category. This means that the PBL model implemented has a stronger influence than that of conventional learning in improving students' critical thinking ability. Thus, the PBL model can be recommended as an alternative learning model in improving students' critical thinking ability in physics learning on the topic of optical instruments.

ABSTRAK

Penelitian bertujuan untuk mengungkap pengaruh model Problem Based Learning (PBL) terhadap kemampuan berpikir kritis siswa pada materi alat optik. Penelitian ini adalah penelitian kuasi eksperimen dengan Pre-test and Post-test Design. Subjek penelitian ini adalah siswa kelas X MAN 3 Malang. Kelas eksperimen dan kontrol, masing-masing menerima model PBL dan model pembelajaran konvensional. Instrumen penelitian ini adalah Tes Kemampuan Berpikir Kritis Alat Optik yang berupa 14 butir soal essay dengan reliabilitas alpha Cronbach 0,78. Data penelitian dianalisis dengan menggunakan beberapa uji antara lain uji-t, N-gain, dan size effect. Hasil analisis tersebut menunjukkan bahwa implementasi model PBL berhasil meningkatkan kemampuan berpikir kritis siswa lebih tinggi daripada pembelajaran konvensional. Kelas eksperimen mampu mencapai kategori N-gain score tinggi, sedangkan kelas kontrol pada kategori medium. Penelitian ini mampu mencapai size effect kategori "besar". Hal ini berarti model PBL yang diimplementasikan memiliki pengaruh kuat daripada implementasi pembelajaran konvensional dalam meningkatkan kemampuan berpikir kritis siswa. Dengan demikian, model PBL dapat direkomendasikan sebagai salah satu model pembelajaran alternatif dalam peningkatan kemampuan berpikir kritis siswa dalam pembelajaran fisika pada topik instrumen optik.

Keywords: Critical Thinking Ability; Problem Based Learning

INTRODUCTION

One of the objectives of Physics learning is to foster students' thinking ability that are important in solving problems in daily life (Ministry

of National Education, 2014). Thinking ability that can be developed through physics is critical thinking. Critical thinking is a process of reasoning and logical thinking that is focused on making decisions about what to do or Believed (Ennis, 2011) and is reflective include interpretation, inference, self-regulation, analysis, explanation, and evaluation (Facione, 2011).

Optics is one of the topics in physics

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that discusses the concept of light in reflection processes by mirrors and refraction by lenses, which can be used to explain light phenomena in everyday life. These light phenomena can be captured by both eyes directly or by using certain tools called optical instruments. Optical devices are the result of the design of a combination of mirrors and/or lenses that form certain images to capture expected light phenomena such as telescopes, cameras, binoculars, etc. (Serway & Jewett, 2014).

Learning about optical instrument has been carried out in MAN 3 Malang and the results of preliminary observations indicate that students' critical thinking ability about the topic of optical instrument is still poor with an average score of 42.4. Data from classroom observations on teacher performance showed that the teaching and evaluations processes about optical instrument topics have not been oriented to developing students' critical thinking ability. The teacher still uses conventional models in learning and the problems presented in the evaluation are still at the level of memorization and the application of formulas. Whereas based on the results of research by Rofiah, Aminah, & Ekawati (2013) explaining that to train students thinking ability the evaluation questions presented should contain questions that can test students thinking ability such as problem solving, critical thinking, and creative thinking.

Based on the results of preliminary findings, the learning model that can facilitate students' critical thinking ability is necessary to be applied in physics learning on the topic of optical instrument. One of the learning models recommended in the 2013 Curriculum in Indonesia is Problem Based Learning (PBL). PBL is an active and student-oriented learning that encourages students to think and solve problems (Aslihan & Mustafa, 2014). PBL is also known as guiding rather than directive and also process oriented which directs students independently to solve problems (Sulaiman & Eldy, 2014). Regarding the improvement of students' critical thinking, the results of Nusawidya's research (2014) as well as Jalani and Sern (2015) showed that students' critical thinking ability were taught with PBL models higher than students taught with conventional models.

In general, the implementation of PBL goes through phases starting from student orientation to the problem, organizing students, guiding individual and group investigations, developing and presenting results, and analy-

zing and evaluating the process and results of problem solving (Arends, 2012). Overall, these phases can be a means for students to improve their critical thinking ability. Critical thinking ability in this study used 7 of the 12 indicators of Ennis's critical thinking ability (2011), namely (1) asking questions and answering questions that needed explanation, (2) considering credibility (criteria of a source), (3) observing and considering observations, (4) make deductions, (5) do induction, (6) make value decisions, and (7) decide on an action. Therefore this study aims to reveal the influence of PBL on students' critical thinking abilities.

METHODS

This study used a quasi-experimental design with pre and posttest design as proposed by Creswell (2012). The subjects of this study were students of class X of MAN 3 Malang with 28 students in each experimental class and control class. The experimental class experiences learning using the PBL model, while the control class obtains conventional learning.

The instrument of this study is the Optical Instrument Critical Thinking Ability Test consisting of 14 essay questions to reveal the profile of students' critical thinking about the concept. This instrument had Cronbach's alpha reliability score of 0.78. To determine whether there is a difference in critical thinking ability of students between the experimental and control classes, t-test analysis was performed on the final test results data with a significance level of 0.05 (Leech, Barrett, & Morgan, 2005). If the test results show a significant difference, a better learning model is one that has a higher average. Furthermore, the critical thinking ability data were analyzed by normalized gain scores for the average class, namely the actual grade gain score divided by the possible maximum average class gain (Hake, 1998), and the Cohens effect size calculation (Leech et al., 2005). The gain score describes the magnitude of the increase in pre and posttest, while the effect size is the index of practical significance that describes the magnitude of the difference.

RESULTS AND DISCUSSION

The learning process in the experimental class has the following description. Learning activities begin with student orientation to the problem. Problems are presented in the form of demonstrations where two students with

glasses are asked to distinguish reading results when using glasses and without glasses. Then the two students were asked to exchange their glasses. The data delivered by the two students was used as material for class discussion to analyze the usefulness of the glasses for their glasses-wearing friends and how the glasses work in producing the right image on the retina.

In the second phase, namely organizing students for learning, students are grouped into 6 with 4-5 students in each group. In the third phase, namely guiding individual and group investigations, students are asked to conduct experiments according to student worksheets provided by the teacher about eyes and glasses. The worksheet is also equipped with discussion questions that must be answered by students.

In the fourth phase, namely developing and presenting the work, students carry out activities to process experimental data, present data in the form of tables or graphs guided from discussion questions on the worksheet. In the fifth phase, which is analyzing and evaluating the problem solving process, each group is asked to present the results of their experiments in front of the class and get responses from other groups. During the presentation process the teacher guides the discussion and provides reinforcement to the explanations of the results of each group. At the end of the discussion the teacher asks students to conclude the results of the lab work that has been done. In the next activity, students are directed to answer back the problems raised at the beginning of learning based on the concepts they obtained through practicum and continued with an explanation of eye material and glasses by the teacher.

In the closing activity, the teacher guides students to conclude the learning that has been done by referring to the learning indicators. Then the teacher gives a formative test to evaluate learning.

The pretest and posttest data of students' critical thinking ability were presented in Table 1 and Table 2. From Table 1 it appears that the initial conditions of the two classes are relatively the same. The experimental class and the control class get scores of 48.9 and 46.6 respectively. But this is not the case with the final critical thinking ability in posttest data (Table 2). The experimental class achieved a higher score (86.9) than the control class score (81.5).

Table 1. Student's Critical Thinking Scores on Pretest

| Parameter | Experiment Class | Control Class |
|--------------------|------------------|---------------|
| Number of Students | 28 | 28 |
| Lowest Scores | 38.0 | 36.0 |
| Highest Scores | 60.0 | 60.0 |
| Average | 48.9 | 46.6 |
| Deviation Standard | 7.88 | 7.28 |

Table 2. Student's Critical Thinking Scores on Posttest

| Parameter | Experiment Class | Control Class |
|--------------------|------------------|---------------|
| Number of Students | 28 | 28 |
| Lowest Scores | 74.6 | 69.6 |
| Highest Scores | 96.0 | 93.6 |
| Average | 86.9 | 81.5 |
| Deviation Standard | 5.83 | 7.68 |

That is, PBL learning in the experimental class is able to improve students' critical thinking ability better than that in conventional learning in the control class.

The increase in the posttest score from the pretest score is presented in Table 3.

Table 3. Summary of Score of Students' Critical Thinking Ability

| Parameter | Exp. Class | Control Class |
|------------------------|------------|---------------|
| Pretest Score Average | 48.9 | 46.6 |
| Posttest Score Average | 86.9 | 81.5 |
| Gain | 38.3 | 34.9 |

From Table 3 shows that the experimental class has a higher increase in critical thinking ability than that in the control class. That is, PBL learning in the experimental class is able to encourage an increase in students' critical thinking ability better than that in conventional learning in the control class.

The similarity test of the initial state has prerequisites, namely the test for normality and homogeneity. The Lilliefors test result an experimental class $L_o = 0.146$ and control of $L_o = 0.145$ which lower than L_{table} (0.161) so that both of the pretest data obtained by students are normally distributed. The homogeneity test of pretest data yielded F_{count} of 1.17) which lower than F_{table} (1.84) so that the second the

data group has the same or homogeneous variant. Since the data is normal and homogeneous, the similarity test of the initial state using the t-test. This t-test resulted $t_{\text{count}} = 0.97$ which lower than $t_{\text{table}}(2)$ with a significance level of 0.05 so that there is no difference in initial abilities between the experimental class and the control class. This equal initial situation is important in the study of quasi-experimental types. Both classes have the same level of critical thinking ability when the treatment starts with different actions between the two. If there are differences in critical thinking ability at the end of learning, the differences occur solely due to differences in the treatment of actions between the two.

The difference test for posttest data uses the prerequisite test and the same statistic with the initial similarity test. Lilliefors test of posttest data resulted in the experimental class having $Lo = 0.084$ and control $Lo = 0.154$ which was smaller than $L_{\text{table}} = 0.161$ so that the two posttest data of students were normally distributed. The posttest homogeneity test results $F_{\text{count}} = 1.73$ which lower than $F_{\text{table}}(1.84)$ so that the two data groups have the same or homogeneous variants.

Since the data is normal and homogeneous, the posttest difference test uses the t-test. This test resulted $t_{\text{count}} = 2.96$ which higher than $t_{\text{table}}(2)$ with a significance level of 0.05 so that there are differences in critical thinking ability between the experimental class and the control class. The average score of the experimental class is higher than the average score in the control class. Thus, it can be concluded that PBL learning in the experimental class is able to improve students' critical thinking ability better and significantly than that in conventional learning in the control class.

Some studies show the superiority of PBL in improving students' critical thinking abi-

lity. Nusawidya (2014) showed that the group of students taught with PBL models had better critical thinking ability than the group of students who were taught with conventional learning. In addition, the research on Jalani & Sern (2015) shows that students' critical thinking ability taught with the PBL model are higher than those in students who are taught with conventional learning models. Nurlaila, Suparmi, & Sunarno (2013) explained that the experimental class that applied PBL with problem solving was able to improve critical thinking ability, student learning outcomes and creativity. In addition to the PBL model, several other learning models can also improve critical thinking ability, such as Learning Cycle-7E (Hartono, 2013) and guided inquiry (Kurniawati, Wartono, & Diantoro, 2014).

The pretest and posttest data along with the increase in each indicator of critical thinking ability are presented in Table 4. From Table 4 it appears that the initial condition of each of the 7 indicators of students' critical thinking ability is relatively the same between the experimental class and control control. But, after treatment the experimental class PBL model had the seven indicators higher than the control class. This means that the experimental class has better critical thinking ability than the control class, both totally and individually each indicator.

From Table 4 it also shows that the increase in each indicator pretest to posttest in the experimental class is higher than that of the control class. In the first indicator, which is asking and answering questions that need explanation, the experimental class has a slightly higher increase than the control class. The experimental class trains this indicator in the first phase, namely orienting students to the problem, and the fifth phase, which is analyzing and evaluating the problem solving process.

Table 4. Pretest, Post-test, and Improvement of Each Indicator of Critical Thinking

| Indicators of Critical Thinking | Experiment Class | | | Control Class | | |
|--|------------------|------|------|---------------|------|------|
| | Pre | Post | Gain | Pre | Post | Gain |
| Asking questions and answering questions that need explanation | 60.4 | 90.4 | 30.2 | 56.1 | 86.4 | 29.9 |
| Considering the credibility of a source | 36.8 | 86.6 | 49.8 | 35.6 | 80.3 | 44.7 |
| Observing and considering observations | 42.1 | 84.5 | 42.4 | 46.3 | 79.6 | 33.3 |
| Conducting deduction | 48.1 | 85.8 | 37.7 | 46.4 | 81.3 | 34.9 |
| Conducting induction | 52.6 | 86.7 | 34.1 | 47.5 | 81.2 | 33.7 |
| Assessing a decision | 50.8 | 89.8 | 39.0 | 43.9 | 82.6 | 38.7 |
| Deciding on an action | 51.6 | 84.2 | 32.6 | 50.4 | 78.5 | 28.1 |

Problems presented at the beginning of learning can trigger students' curiosity so that they can become a place for students to explore the world around them (Widodo, 2013). Furthermore, referring to the problem students are trained to answer a question that requires explanation. This is in accordance with the steps of solving problems, namely identifying and analyzing problems (Yu, Fan, & Lin, 2014). After conducting discussions, students are asked to answer the problems raised at the beginning of learning. The control class lacks training in this indicator because there are no problems at the beginning of learning.

On the second indicator of critical thinking ability, namely considering the credibility of a source, the experimental class experienced a fairly higher increase than the control class. This indicator is trained in the fourth phase, namely developing and presenting the work. At this stage students must analyze the data they obtained through experiments by comparing the results of experiments with existing theories. It seems that students can take advantage of problem orientation in the first phase as a provision in conducting experiments and analyzing data.

In the third indicator of critical thinking ability, namely observing and considering the results of observations, the experimental class experienced a higher increase than the control class. This indicator is trained in the third phase, namely guiding individual and group investigations. This activity involves students conducting an investigation / exploration of the environment in solving problems (Barrett, 2010) which indirectly trains students' critical thinking not to easily believe in the information obtained and investigate the source of information so that learning is more meaningful. The experimental class student worksheet adds the indicator so that the student is indeed trained in the indicator, while the control class worksheet does not add the indicator so that the student is indeed not trained on the indicator.

In the fourth indicator of critical thinking ability, namely deduction, the experimental class experienced a fairly higher increase than that in the control class. This indicator is trained in the second phase, which is to organize students to learn. At this stage students must answer questions that require deduction ability on the worksheet. In the control class there were no pre-experimental questions so that they were not trained to do deduction indicators.

In the fifth indicator of critical thinking abi-

lity, namely induction, the experimental class experienced a higher increase than that in the control class. This indicator is trained in the fifth phase, which is analyzing and evaluating the problem solving process. In the experimental class, learning conclusions refer to indicators of competency achievement, namely seven indicators of selected critical thinking ability. According to Ennis (2011), decision making or conclusion must come from observations, statements from several sources, and arguments that were previously accepted. In the experimental class conclusions are based on the results of observations made by students.

In the sixth indicator of critical thinking ability making decision values, the experimental class experienced a higher increase than that in the control class. This indicator is trained in the fifth phase, which is analyzing and evaluating the problem solving process. When the teacher gives an explanation of the material after the students carry out the experiment, students are trained to make decision values in the form of examples of questions that refer to the indicators of critical thinking. So at this stage, indicators of critical thinking make the value of decisions can be trained.

On the indicator of the seven critical thinking ability, namely deciding an action, the experimental class experienced a higher increase than the control class. Students are trained to decide on an action in the form of solving formative test questions. Both classes both received formative tests, but the experimental class had undergone a series of phases of the PBL model while the control class experienced conventional learning as usual.

The experimental class has a normalized gain score of 0.74 in the high category, while the control class is 0.65 in the medium category. It appears that the normalized gain score of the class average from the experimental class is higher than the control class. That is, PBL model learning in the experimental class is able to produce students' critical thinking ability that are higher than that of conventional learning in the control class. This is in accordance with the research of Lismayani (2017) that the experimental class PBL produces a higher gain score than that in the control class. Gain score gains for students from the experimental and control classes have exceeded the average gain limit that is usually achieved in learning involving active students, which is equal to 0.48 (Jackson, Dukerich, & Hestenes, 2008).

Analysis of the data on critical thinking

ability of the experimental class and control students produced effect size practical significance of $d = 0.80$ in the "large" category. Based on these results it can be said that operationally the implementation of PBL model learning practices has a high influence than conventional learning in order to improve students' critical thinking ability.

The results of this study indicate that the critical thinking ability of students who are taught with the PBL model are higher than the critical thinking ability of students who are taught by conventional learning models. According to Sulaiman and Eldy (2014), PBL models are able to train one thinking ability, namely the ability to think critically. In the experimental class, students are faced with contextual problems in the form of videos or demonstrations, while in the control class there is no student orientation to the problem at the beginning of learning. The problems raised will be resolved through practical activities with instructions in the form of worksheets. The worksheets used in the experimental class and the control class are also different. In the experimental class, the worksheet used is adjusted to the PBL model, while in the control class, the worksheet used only has goals, tools and materials, experimental procedures, observation data, data analysis, and conclusions. On the experimental class worksheet there are also aspects of critical thinking ability, whereas in the control class worksheet there is no aspect of critical thinking ability.

PBL applied in this study is a series of learning activities that emphasize the process of solving problems that are carried out scientifically. The process of problem solving in PBL can be motivating, challenging, and enjoyed by students during learning (Masek & Yamin, 2011). The problem solving process in question begins with identifying and analyzing problems, gathering information, presenting solutions and evaluating solutions (Yu et al., 2014; Karatas & Baki, 2013). The steps to solving the problem are trained in the learning process in accordance with the phases in PBL.

CONCLUSION

Based on the results of the research and discussion above, the following conclusions can be made. Critical thinking ability of students learning with PBL models is significantly higher when compared with students who study with conventional learning models, which are cha-

racterized by the acquisition of an experimental class average score of 86.9 higher than that in the control class with a score of 81.5 in with a significance level of 0.05. The experimental class gained a 0.74 high score gain score, while the control class was 0.65 medium category. The effect size calculation in this study is 0.80 in the "large" category, which means that operationally the implementation of PBL model learning practices has a greater effect strength or influence than that in conventional learning in order to improve students' critical thinking ability.

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