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The Effect of HOT-Lab to Improve Critical Thinking Skills of Prospective Physics Teachers

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The aim of this research is to know the effectiveness of the Higher Order Thinking Laboratory (HOT Lab) in improving critical thinking skills of prospective physics teachers on the concept of heat transfer compared with the application of verification lab. This research used quasi-experiment research method with control group pretest-posttest design. The subject of this research was students of Physics Education Program of UIN Sunan Gunung Djati Bandung. The sample of the study was 60 students which were divided into two groups covering of experimental and control group, consists of 30 students. The number of female sample in the experimental group was 18 people and the male was 12 people. The instrument to measure Critical Thinking Skills (CTS) was essay test. Data were then analyzed using average n-gain, effect size, and t-test. The results showed that critical thinking skills of students using HOT Lab were higher than that using verification lab. Female student who applied the HOT lab showed higher critical thinking skills than male student. It is concluded that the implementation of HOT Lab on the concept of heat transfer had a greater effect in enhancing critical thinking skills of prospective physics teachers than the application verification lab.

Keywords: Higher Order Thinking (HOT) Lab, Critical Thinking Skills (CTS), Prospective Physics Teache

1. INTRODUCTION

Higher education should prepare students to the master variety of high-level thinking skills to meet both internal and external challenge in the face of the 21st century[1]. One of the skills to train and develop for pre service teacher is Critical Thinking Skills (CTS). CTS can be trained and developed through the process of science learning in group room or activities in the laboratory. The purpose of science education is to help learners to develop their understanding of scientific knowledge and the scientific method. Along with the development with the demands of society and the world of work, physics learning should train and develop critical thinking skills for learners.

Laboratory activities in physics learning are recommended by educators and researchers to be applied in science education as the strategy to improve higher order thinking skills (critical thinking skills) in the 21st century[2-5]. Students will have wider opportunity to develop their reasoning and thinking skills through the process of science in constructing or applying the concept during laboratory activities. Hence, needs to develop laboratory design can improve the ability to think critically. The HOT lab developed from model the problem-solving laboratory.[1] HOT Lab is a relatively new laboratory design; it is claimed as an innovative laboratory design that can be used to enhance CTS of students.

Critical Thinking Skills (CTS) have been defined by many experts and regarded as the thinking skills that students must have and develop[6-8]. CTS are one of the pedagogical skills that need to be mastered by prospective teachers[9]. Research using various strategies and learning models to enhance critical thinking skills that have been previously done with guided inquiry learning models[10], inquiry-based instruction[11], problem-based learning[12,13], collaborative work approach[14], training, and development personnel model[15].

2. METHODS

The study's object was the reading learning material using literation-based DRTA strategy in 4th class of Elementary school. The learning material was developed by basic competence (KD) of School-based Curriculum (KTSP), while the preliminary field test was done in 4th class with 48 students in at SDN 79 Pekanbaru.

The method used in this study was a quasi-experiment method with control group pretest-posttest design. This research used two_group, experiment group and control group. The developed HOT Lab model consists of 11 stages: (1) real-world problem; (2) determination and evaluation ideas; (3) experiment questions; (4) materials and equipment; (5) prediction; (6) question method; (7) exploration; (8) measurement; (9) analysis; (10) conclusion; and (11) presentations. This HOT lab model was applied in the experimental group for the topic of heat transfer. The verification lab is used in the control group which includes 9 steps. Meanwhile, stage of verification lab consisted of: (1) aim; (2) theory; (3) materials and equipment; (4) preliminary task; (5) trial procedure; (6) measurement; (7) analysis; (8) conclusion; (9) end task.

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The subjects of this research were students of Physics Education Program UIN Sunan Gunung Djati Bandung in 2015/2016 academic year. The sample of this research was 60 students which were divided into two groups covering experimental group and control group of 30 students respectively. The number of female samples in the experimental group was 18 people and the male was 12 people.

The instrument utilized in this research was an essay test, to measure CTS of prospective physics teachers on the concept of heat transfer. The developed CTS indicator refers to the Binkley et al framework[16] and is adopted by Adam et al[17], which includes aspects of CTS 1 Explain; CTS 2 Analyze; CTS 3 Interpret; CTS 4 Synthesize; CTS 5 Inference; and CTS 6 Evaluate.

The enhancing data of prospective physics teachers' critical thinking skills were analyzed by using average normalized gain score <g> with Hake criteria: $\langle g \rangle < 0.3$ (low); $0.3 \leq \langle g \rangle \leq 0.7$ (moderate); and $\langle g \rangle > 0.7$ (high)[18]. After that, a statistical calculation was done to test the hypothesis starting from counting normality, homogeneity, and t-test.

Calculation size effect was also done to count the difference mean standard, to know the effect of the application of the hot lab on increased capacity in think critically prospective physics teacher's compared with verification lab. The effect sizes are then correlated with the criteria made by Cohen as follow: $0.0 < d < 0.2$ (minor effect); $0.2 \leq d \leq 0.8$ (medium effect); and $d \geq 0.8$ (large effect)[19].

3. RESULTS AND DISCUSSIONS

The enhancing of CTS of prospective physics teacher is analyzed by calculating the normalized gain average <g> then interpreted according to Hake criterion. The data needed to calculate the CTS of student increase is the pretest and posttest of the experiment and control groups. N-gain CTS for groups using HOT lab and verification lab is shown in Figure 1.

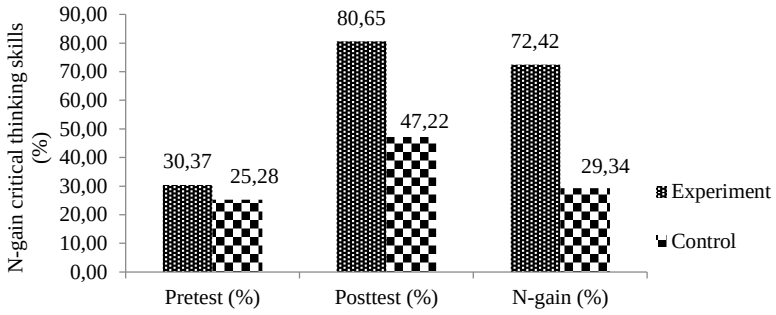

Figure 1. Normalized Gain Average of CTS of Students

The normalized gain average of CTS of students of implementing HOT Lab is much greater than that of using verification lab. Details of the increase in normalized gain average in the group using HOT Lab include the moderate category of 9 people and the high category of 21 people. Overall improvement CTS of students in groups using HOT Lab was the high category. Details of the increase in the normalized gain average in groups using verification lab included low categories of 16 people and moderate categories of 14 people. Overall, the improvement of CTS of students in the group implementing verification lab was a low category.

The result of calculation of normality data of CTS of students in both groups showed normal, each value 0.901 and 0.856. Based on homogeneous calculation obtained the value of 0.419 which shows both homogeneous data. The result of t-test with $\alpha = 0.05$ was obtained by significance value 0.000; this indicated that there was a significant difference in CTS of students who were implementing HOT Lab beside verification lab. The normalized gain average for each aspect of CTS of students in both groups as shown in Figure 2.

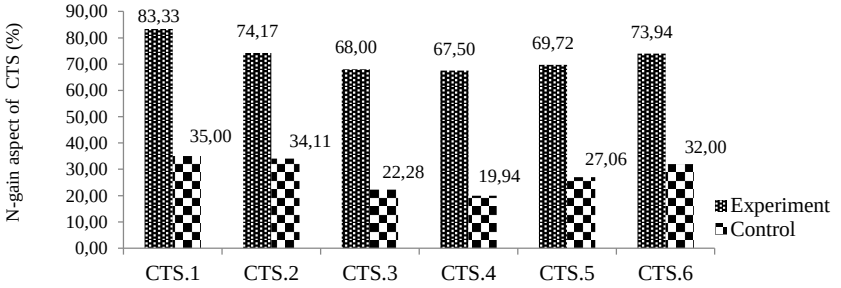

Figure 2. Normalized Gain Average of Aspect of CTS

Figure 2 describes that student's CTS on aspects of CTS 1, CTS 2 and CTS 6 for both groups are increasing. The improvement of three aspects of CTS of students in the group using HOT Lab (include high category) is higher than lab verification (include medium category). The CTS of students on the aspects of CTS 3, CTS 4, and CTS 5 in both groups have improved as shown in Figure 2. The improvements of those aspects are in the medium category in the group using HOT Lab and verification lab is low level.

The greatest increase of normalized gain average is in the CTS 1 aspect for both HOT Lab and verification lab. Students who applied HOT Lab could explain experiment steps, results, and claims. These three actions are trained in real-world problem activity, making analysis, drawing conclusions and presenting results. The students, who implemented the verification lab, do the activity laboratory in accordance with the experimental steps that have been determined and do not explain the results obtained.

The aspect of CTS 2 in the group using HOT Lab showed bigger improvement than in the verification lab. The activity of measurement and analysing in the HOT lab made students to learn related to analysing the outcome of data and to test the compliance with predictions as well as the analysis result serve as a basis for making conclusions. The CTS 2 aspect of the verification lab is less likely to be developed, as students analyze the results of the experiments obtained to suit the data contained in the reference and if the experimental results do not match the data in text, the student investigated the factors causing the difference. This fact shows physics and technical students are facing adversity in analysing experimental data[20, 21].

The improvement CTS 3 on the group using HOT Lab was higher than in verification lab. Students who applied HOT Lab did some activities such as categorizing information, proposing ideas, making arguments and claims. All of those activities were developed along the determination and evaluation ideas and analysis. Students interpret the data of the lab results in tables and graphs to analyze the relationship between variables. The students who applied verification lab should adhere to the experimental steps that have been determined. The ability of students to interpret data is an essential part of the activity laboratories physics and science[22].

The improvement aspect of CTS 4 showed the lowest N-gain in both groups using the HOT Lab and verification lab. Even though, the increase in the HOT Laboratory is still higher than the verification lab. Stages of answering

experimental questions and method questions as well as exploring in the HOT Lab make students able to synthesize and associate data obtained with arguments when presenting results. Students implement verification lab only synthesized data onto an emphasis on the concept quantitatively. The competency focus developed in the verification laboratory describes and supports the concepts learned by the students, oriented in teaching how to conduct investigations and lacking the ability to think[23].

Students in the group using the HOT Lab showed an improvement in aspects of CTS 5 greater than the students in the verification laboratory. Students who apply HOT Lab can make inferences by analysing the measurement results to be associated with predictions that have been stated in the previous stage. Student inference capabilities are developed at the stage of measurement and analysis and conclusions. Students applying the verification laboratory undertake a predetermined variable measurement and summarize the experimental results according to pre-determined experimental objectives.

The N-gain aspect of CTS 6 in the group using the HOT Lab was in the higher category greater than the students that applied the verification lab including the low level. Students' ability to evaluate and re-evaluate options when finding contradictory evidence developed at the stage of determining and assessing ideas, answering predictions and summarizing. Students who apply the verification laboratory are not trained in their evaluation ability due to practicum in accordance with prescribed procedures. The application of verification lab makes students less aware of what is being implemented and what should be evaluated when results are not as expected[24].

The results of the effect size calculation showed the implementation of HOT Lab in improving the ability to think critically 4.63. Based on criteria Cohen[19]; this means using the HOT Lab gave a big effect. Thus the implementation of HOT Lab provides a great effect of enhancing CTS of students.

The average difference in n-gain CTS of students by sex is shown in Figure 3.

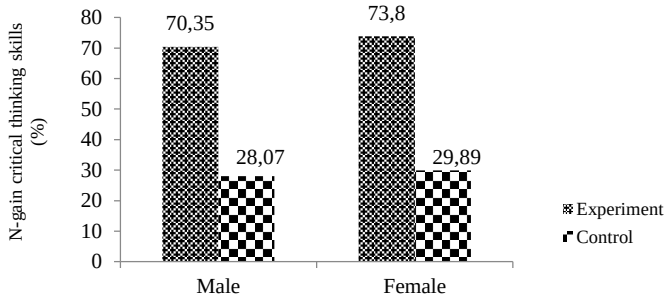

Figure 3. Average N-gain of CTS by gender

Female student's CTS were higher than male students. The difference CTS of students occurred in both of group using HOT Lab and verification lab. The improvement CTS of female and male in the group using HOT Lab were high category while in the group using verification lab were low level.

Details of the increase in N-gain in the group using HOT Lab for men included in the medium and high category were 6 people respectively, while for female included moderate category 3 people and high category 15 people. Details of the increase in N-gain in the group using the laboratory for male verification included low category 5 people and the moderate category 4 people. While for women is including the low category 11 people and moderate category 10 people.

The result of normalized gain average normality accounted for students' CTS by gender in experiment group using HOT Lab between male and female students, each of the 0.841 and 0.311 values is both normal. Based on homogeneous calculation obtained both inhomogeneous data. The result of calculation of Mann-Whitney with $\alpha = 0.05$ obtained value level of significance equal to 0.024, this indicates there was a significant difference in the CTS of female compared to male after applied HOT Lab.

The calculation of for each student's CTS indicator by gender has been done for the group using the HOT Lab. The calculation results are shown in Figure 4.

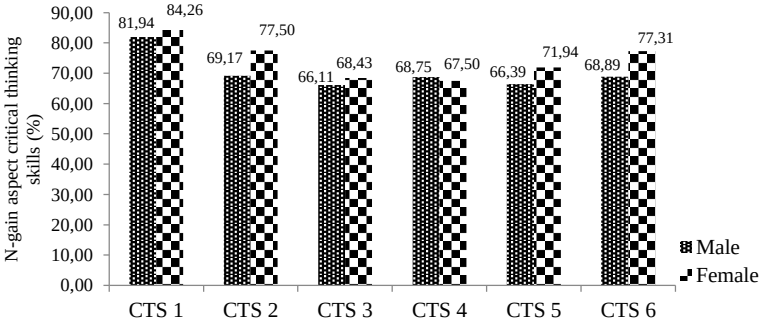

Figure 4. Average N-gain of each aspect of CTS by gender

The aspects CTS 1, CTS 2 CTS 5, and CTS 6 for both genders similarly increase. The enhancing of four aspects of CTS of the female was bigger than the male. The improvements to those four aspects in the female were in the high category; in medium category for the male except aspect of CTS 1 include the high category. The aspect of CTS 3 in both genders has enhanced as shown in Figure 2. The improvements in this aspect were in the medium category in the female and male students. The aspects of CTS 4 were included in the middle category in both male and female. The increasing in this aspect was different from that of the other on male students.

The HOT Lab design was developed from the problem solving design of laboratory, especially in the real problem that emphasizes the rich context, contains the limitations and contains various alternative answers[25]. Various activities in HOT Lab were developed to provide transferable skills of students including CTS. Transferable skills can be used by students in the context of everyday life as well as in the work environment.

Laboratory activities provide a rich learning experience that can help students comprehend concepts comprehensively and develop students' hands-on and mind on skills[26, 27]. The contribution to laboratory activities is expected to

improve conceptual capabilities, foster innovation, stimulate creativity and develop critical thinking in judgment as part of the learning experience. Laboratory activities have an important role and affect students' attitudes to science both in the classroom and at school[28]. The results showed that the application of laboratory verification has not been able to develop the students' CTS optimally because it practices the ability of laboratory activities. Laboratory verification has some pedagogical deficiencies, especially with regard to student involvement in high-level thinking in creating and presenting laboratory activity reports[29].

4. CONCLUSIONS AND SUGGESTIONS

We have successfully studied the effect of HOT Lab in improving CTS of students. The category of enhancing CTS of students using HOT Lab was high while those implement the verification lab are low level. In sum, the application of HOT lab on the concept of heat transfer provided a significant effect in improving students' critical thinking skills. The results also showed that gender influences a person's critical thinking skills; the female had better critical thinking skills than male.

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