Learning Experience on Transformer Using HOT Lab for Pre-service Physics Teacher’s

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Abstract. This study aimed at investigating pre-service teacher’s critical thinking skills improvement through Higher Order Thinking (HOT) Lab on transformer learning. This research used mix method with the embedded experimental model. Research subjects are 60 students of Physics Education in UIN Sunan Gunung Djati Bandung. The results showed that based on the results of the analysis of practical reports and observation sheet shows students in the experimental group was better in carrying out the practicum and can solve the real problem while the control group was going on the opposite. The critical thinking skills of students applying the HOT Lab were higher than the verification lab. Critical thinking skills could increase due to HOT Lab based problems solving that can develop higher order thinking skills through laboratory activities. Therefore, it was concluded that the application of HOT Lab was more effective than verification lab on improving students' thinking skills on transformer topic learning. Finally, HOT Lab can be implemented in other subject learning and could be used to improve another higher order thinking skills.

1. Introduction
Laboratory practice is a set of activities in the laboratory including demonstrations, computer simulations complementing experiment works for hand on, offering students a rich learning experience, gaining a conceptual understanding of disciplines and developing practical skills [1, 2]. The demands of laboratory practice in schools to face the 21st century have been widely suggested by science educators since many benefits are derived from these laboratory activities [3, 4]. According to Carin [6] through laboratory practice, learners will acquire various skills such as manipulating materials, observing, grouping, measuring, using number skills, recording data, replicating, identifying variables, interpreting data, predicting, formulating hypotheses, inferring, generalizing, creating models, and making decisions.

Laboratory activities conducted in schools have not been managed effectively; the type of experiment practiced is too simple and less worthy. Students are only required to report the observations, but are rarely asked to analyze the interrelationship between the observed variables, test predictions, or selecting some possible explanations of the research results; the activities carried out are still structured, and less arouse students’ curiosity [5, 7]. The existence of the needs of providing laboratory practice to improve critical thinking skills stimulates the development of Higher Order
Thinking (HOT) Lab. Steps in the HOT lab are the results of merging the creative problem solving and problem-solving lab. From the merging of these models, the HOT Lab design steps are then compiled, and they consist of five general processes: 1) understanding the challenges, 2) producing ideas, 3) preparing laboratory practice activities, 4) conducting laboratory practice, and 5) communicating & evaluating the results of activities [8]. Every activity in the HOT Lab promotes both convergent thinking skills (critical thinking) and divergent thinking skills (creative thinking).

The topic of transformers is significant to learn, considering the application of the concept of transformer is widely used in electronic devices in everyday life. A transformer is a device for introducing mutual coupling between two or more electric circuits. The term iron-core transformer identifies the coupled coils, which are wound on a magnetic core of laminated specialty steel to confine the flux and maximize the coupling. Air-core transformers are found in electronic and communications applications. A third group consists of coils wound over one another on a nonmetallic form, with a movable slug of magnetic material within the center for varying the coupling [9]. In its simplest form, the AC transformer consists of two coils of wire wound around a core of iron. Transformer consists of two types of step up transformer and step down transformer. The relationship between the voltage and the coil in the transformer is written in the equation (1).

\[ V_2 = -\frac{N_2}{N_1}V_1 \]  

(1)

When \( N_2 > N_1 \), the output voltage \( V_2 \) exceeds the input voltage \( V_1 \). This setup is referred to as a step-up transformer. When \( N_2 < N_1 \), the output voltage is less than the input voltage, and we have a step-down transformer [10]. In an ideal transformer, where there are no losses, the power \( I_1V_1 \) supplied by the source is equal to the power \( I_2V_2 \) in the secondary circuit, in equation 2 [10].

\[ I_1V_1 = I_2V_2 \]  

(2)

The studies on improving critical thinking skills have used a variety of strategies and learning models such as problem-based approach [11], the application of writing strategy [12], collaborative approach work [13], and guided inquiry learning model [14]. However, studies on improving critical thinking skills through laboratory activities, conducted in colleges, are considered as innovation. This research used mix method with the embedded experimental model. The results showed that the critical thinking skills of students in the experimental group were higher than the control group. Finally, HOT Lab can be implemented in other topic learning.

2. Experimental Method

The research used was mix method with the embedded experimental model. This type is defined by having qualitative data embedded within an experimental design. The priority of this model is established by the quantitative, experimental methodology, and the qualitative data set is subservient within that methodology. This model can either be used as a one-phase or a two-phase approach, in which the timing reflects the purpose for including the qualitative data [15].

The population of this study was all students of Physics Education of UIN Sunan Gunung Djati Bandung at semester V academic year 2015/2016. The samples used in this study were 60 students consisting of 30 students (12 male and 18 female) of the experimental group and 30 students (9 male and 21 female) of group control. The sampling technique used was simple random sampling.

The experimental group, in practicum on the transformer used HOT Lab design, consisting of 11 phases of activities including real-world problems, determining and evaluating ideas, asking experimental questions, providing materials and equipment, predicting, applying question method; exploring, measuring, analyzing, concluding, presenting. While the control group used a design verification lab consisting of 9 stages of activities including giving purposes, delivering basic theory, providing tools and materials, giving a preliminary assignment, giving trial procedures measuring, analyzing, concluding, and end task.
The instruments used in this research were observation sheet, interview protocol and critical thinking skill test in the form of essay. Observation sheets are used to view the activity of all phases in practicum guide HOT Lab. Assessment of HOT Lab implementation used scale 1-3. The developed Critical Thinking Skills (CTS) indicator refers to the Binkley et al. framework, which includes aspects of CTS 1 Explain. State results, justify procedures, and present arguments; CTS 2 Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems; CTS 3 Interpret information and draw conclusions based on the best analysis; CTS 4 Synthesize and make connections between information and arguments; CTS 5 Inference. Query evidence, conjecture alternatives, and conclude, and CTS 6 Evaluate. Assess claims and arguments [16]. The improvement of critical thinking skills determines with the gain score \(<g>\) from Hake [17]. The difference enhancement of critical thinking skills between the experimental and control group, the calculation of t-test score was carried out, previously examined for the normality test using One-Sample Kolmogorov Smirnov Test and the homogeneity test used Test of Homogeneity of Variances. Besides to determine the impact of the implementation of the HOT Lab design on improving students' critical thinking skills relative to the application of verification lab, the effect size calculation was performed. The effect size of this study was determined by computing the standardized standard difference (d) with Cohen et al. [18].

3. Result and Discussion
Based on the result of student practicum report and observation sheet in the experimental group show the students understand the concept of a transformer, able to solve real problem, not fixated on the mathematical equation applicable to the topic of a transformer. Also, understand the relationship between variable, understand the function of each tool component, experimental tools in accordance with method questions, able to explore and analyze experimental data and present experimental results clearly and correctly. The opposite result occurs in the student practicum report and the observation sheet in the control group.

Based on the results of interviews in the experimental group, they feel the benefits of the application of HOT Lab, among others: to be more critical in understanding the problems, improving conceptual understanding, practicing creative thinking skills in practicum with the limitations of existing tools and materials, assisting in practicum. Besides, the student can identify relationships among variables, improving skills in using measuring tools, practicing analytical skills in comparing predictions and experimental results. The students' constraints both in the experimental and control groups show that they find it difficult to make the appropriate coil with the problem making it difficult to make the appropriate comparisons.

Transformers allow for easy changes in alternating voltage. Because energy (and therefore power) are conserved \(I_1 V_1 = I_2 V_2\) to relate the currents and voltages in the primary and secondary windings of a transformer. Transformers are useful for transmitting power over long distances. Because the generator voltage is stepped up, the current in the transmission line is reduced, and hence \(I^2R\) losses are reduced. In practice, the voltage is stepped up to around 230 000 V at the generating station, stepped down to around 20 000 V at a distributing station, then to 4 000 V for delivery to residential areas, and finally to 120–240 V at the customer’s site [10].

Based on the results of the research that, the improvement of students' critical thinking skills was shown by calculating the individual N-gain \(<g>\), and then it was averaged and interpreted into the N-gain category. The data required to determine the amount of the improvement of the critical thinking skills were the pretest and posttest results data for both the experimental group and the control group. N-gain critical thinking skills for experimental and control groups can be seen in Table 1.
Table 1. N-gain scores of critical thinking skills of experimental and control groups

| Description                   | Experimental Group | Control Group |
|-------------------------------|--------------------|---------------|
|                               | Pretest            | Posttest      | Pretest            | Posttest      |
| Maximum score (%)             | 44.44              | 77.77         | 30.55              | 52.78         |
| Minimum score (%)             | 30.55              | 91.67         | 19.44              | 36.11         |
| Average score (%)             | 38.25              | 83.24         | 25.19              | 46.57         |
| Standard deviation            | 1.43               | 1.25          | 1.05               | 1.28          |
| Average Gain (%)              | 45.00              | 21.39         |                    |               |
| N-gain (%)                    | 72.94              | 28.63         |                    |               |

Table 1 shows that critical thinking skills scores for both groups were improving. The average improvement score (gain) of students’ critical thinking skills of the experimental group was 45.00% while the improvement score (gain) of the control group was 21.39%. Based on the calculations, the average score <g> of students’ critical thinking skills of the experimental group at 0.73 was categorized high. It was higher than the control group score 0.29 classified into low.

To strengthen the analysis, then the calculation of <g> on each aspect of critical thinking skills of both groups was performed. The calculation results were shown in Figure 1.

Figure 1. Mean N-gain scores of each aspect of critical thinking skills

Respectively:
1. CTS 1. Explain. State results, justify procedures, and present arguments
2. CTS 2. Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems
3. CTS 3. Interpret information and draw conclusions based on the best analysis
4. CTS 4. Synthesize and make connections between information and arguments
5. CTS 5. Inference. Query evidence, conjecture alternatives, and conclude
6. CTS 6. Evaluate. Assess claims and arguments

Figure 1 shows that the critical thinking skills of students in all aspects in the experimental group were higher than the control group. The five aspects of critical thinking skills (CTS 1, CTS 2, CTS 3, CTS 4 and CTS 6) in experiment group were categorized into the high category unless the CTS 5 aspect is included in the moderate category. All aspects of critical thinking skills in the control group fall into the low category.

The N-gain score of the aspect of CTS 1 was the biggest improvement in both the experimental group and control group. Students applying HOT Lab design were able to express and present the results, procedures, or arguments. These were developed at the stage of exploration and presentation in the HOT Lab design. At those stages, students designed and examined circuits or working system of the determined choice of answers to solve problems and present experimental results obtained in the form of verbal and non-verbal. Students applying the verification lab design were told what to measure, execute the established procedures, and not to present the obtained results of the experiments.
The aspect of CTS 2 was the smallest improvement in N-gain occurred in both the experimental and control groups. The increase aspect of CTS 2 students in the experimental group was higher than in the control group. The stages of analyzing activities in the HOT lab design provide a better opportunity for students to think on analyzing the results to examine the compliance with the predictions and analyst produced as the basis for concluding. An aspect of CTS 2 in the control group was less developed since the students analyzed the results obtained to be adjusted with the reference data and analyzed the factors causing the differences. It supports the results of previous studies showing that physics and engineering studies encountered difficulties in analyzing the results of the experiment [19, 20].

The aspect of CTS 3 in the experimental group was greater improved than the control group. Students applying HOT Lab design were able to categorize information, ideas, arguments and claims. It was developed in the prediction, exploration, and measurement stages in the HOT Lab design, therefore students were able to predict the relationship between the variables to be measured in the test and interpret the result data of experiment into tables and graphics. Meanwhile, students applying the verification lab design must follow the determined procedures. Students’ interpreting skills should be developed, since analyzing and interpreting data are necessary for the practice of physics and science in general [21].

The N-gain score of aspect CTS 4 was improved in the high category in the experimental group and the low category in control group. The stages of questioning dealing with experiment and method in the HOT Lab design provided a better opportunity for students to connect the given information by delivering arguments. Students applying verification lab design merely decided details of the analysis and the emphases on the concept (quantitative). It is following the developed focus of competencies on the verification lab design explaining and supporting what students learn, teaching experimental techniques, and less training reasoning skills [22].

The N-gain score of students’ critical thinking skills on the aspect of CTS 5 in the experimental group was improved greater than those in the control group. The improvement was categorized into the medium category in experimental group while in control group include the low category. Students applying HOT Lab were able to collect evidence to solve problems and to draw conclusions based on the analysis. It was developed in the measuring and concluding stages, the students measured the variables related to the problems to be solved and completed the experimental results based on the data analysis. Students applying the verification lab design measured established variables and summed up the results of experiments by the purpose of the predetermined analysis.

The N-gain scores of the aspect of CTS 6 in both experimental and control groups were improved. Students in the experimental group were higher increase than those in the control group. The stages of determining and evaluating ideas and conclusions in the HOT Lab design provided a better opportunity for students to evaluate claims and arguments, and to reevaluate the presented conflicting evidence. Students applying the verification lab design should follow the established procedures. The previous research that the implementation of the cookbook experiments rarely demonstrates the comprehension of what has been carried out [23].

The result of statistical calculation of students' critical thinking skills in experimental class using HOT Lab and control class using verification is shown in Table 2.

| Data type                  | Significance (α = 0.05) | Information | Significance (α = 0.05) | Information |
|---------------------------|-------------------------|-------------|-------------------------|-------------|
| Critical thinking skills  | Normality Experimental  | 0.953       | Homogeneity Experimental | 0.419       |
|                           | Control                 | 0.209       | Normal                 | Homogeneous |
|                           |                         |             |                         | Significant |

Table 2. Statistic calculation of students' critical thinking skills
Based on Table 2 it can be concluded that there is a significant difference in the critical thinking skills of students who were applying the laboratory activities with HOT Lab compared to the verification.

The results of calculation show that the effect size of students' critical thinking was 7.85. According to Cohen [18], this acquisition was considered as big effects. Therefore, it was concluded that the application of HOT Lab design was effective in improving the critical thinking skills of students compared to the verification lab design.

The HOT Lab design has characteristics that enable students to improve their critical thinking skills. The HOT Lab design is the development of creative problem solving and problem-solving laboratory models, with the following characteristics: containing context-rich issues that must be solved through lab practice, applying physics concepts to solve problems, having constraints in problem-solving, demanding creative thinking in problem-solving. Various alternative options are not trivial to solve the problems, and the results of the problem solving are presented.

Lab practice offers students rich learning experiences, gains the conceptual understanding of disciplines and develops practical skills [1, 2]. The contribution of lab practice in instructional science should be able to foster abilities to develop conceptual thinking, generating imagination, stimulating desires and sharpening methodological acumen as a part of an experimental experience. Lab practice is important in learning science in schools, and it determines students' traits toward science in schools and science outside the group room [24].

Based on the results of the above research, it is clear that lab practice implementation using lab verification design does not develop many critical thinking skills of students because it only trains low-level thinking skills. The implementation of cookbook lab model does not benefit the students, particularly the debriefing of science skills, hands-on skills, and even minds-on skills [25].

4. Conclusion
The implementation of HOT Lab design is more effective in improving students’ critical thinking skills compared to the implementation of verification lab design on the electrical circuit materials. Therefore the HOT Lab design implementation seems worth taking into consideration for use in teaching physics in other materials and learning physics in more formal education.

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