Using hot lab to increase pre-service physics teacher’s critical thinking skills related to the topic of RLC circuit

A Malik1,2*, A Setiawan1, A Suhandi1, A Permanasari1, A Samsudin3, D. Safitri4, S A S Lisdiani5, S Sapriadil5, N Hermita6

1Program Studi IPA, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Bandung, Indonesia
2Program Studi Pendidikan Fisika, UIN Sunan Gunung Djati Bandung, Bandung, Indonesia
3Departemen Pendidikan Fisika, Universitas Pendidikan Indonesia, Bandung, Indonesia
4SMAN 2 Sukabumi, Kota Sukabumi, Sukabumi, Indonesia
5Program Studi Pendidikan Fisika, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Bandung, Indonesia
6Program Studi Pendidikan Sekolah Dasar, Universitas Riau, Pekanbaru, Indonesia

*Corresponding author’s e-mail: adammalik@uinsgd.ac.id

Abstract. This research purposes to explore the used of Higher Order Thinking Laboratory (HOT-Lab) in enhancing the critical thinking skills of pre-service teachers related to the topic of Resistors, Inductors, Capacitor (RLC circuit). This study utilised a quasi-experiment method with Pretest-Posttest Control Group design. The sample of the study was 60 students that were divided into two groups covering in experiment and control group, consists of 30 students. The instrument for measuring critical thinking skills is essay test. Data has been analyzed using normalized gain average, effect size, and t-test. The results show that students’ critical thinking skills using the HOT Lab are higher than the verification lab. Using HOT-lab was implemented in the form of activity in the laboratory can improve high-order thinking skills. Hence, it was concluded that the use of HOT Lab had a greater impact on improving students' critical thinking skills on RLC topic. Finally, HOT Lab can be used for other physics topics.

1. Introduction

The era of the global community has forced each individual to have not only knowledge but also skills in order to compete in the 21st century. From all skills possessed by an individual, transferable skills are the main skills needed for work demands since they are portable and can be transferred (ready for use) to complete the job in the workplaces. Transferable skills are skills developed for certain situations that can be developed into other situations [1].

Education paradigm should be in line with the efforts to fulfill the demands of the 21st century. The world of education must prepare graduates in a form of workforces that are able to adapt to the demands of the modern workplaces, and are able to have communication skills, work productively in teams and groups, understand the instructions, see business opportunities priorities, self-evaluation, time management, problem solving, and leadership [2]. Those conditions have given some consequences to the educational institutions at all levels to equip learners to be qualified graduates in a broad sense and
are able to meet the labor market demands requiring mastery of new technologies and a wide range of transferable skills.

Universities should train and develop the skills required by students to deal with internal and external challenges. The internal challenges are educational demands that refer to the enactment of the National Education Standards and National Qualifications Framework of Indonesia. The external challenges of higher education are in form of globalization with the implementation of the ASEAN Economic Community [3].

Trilling, B. & Fadel, C [4] state that current learning activities should contribute to (1) the workplaces and society; (2) practice and talent builds (3) personal and social responsibility (4) values. The design of learning according to the needs of the 21st century has special characteristics: 1) using innovative learning strategies by using modern technology as learning media; 2) integrating cognitive and social skills with teaching contents; and 3) prioritizing the active participation of students [5]. Some studies explaining necessities to develop transferable skills and their assessment have been carried out [6-10].

Laboratory activities can be activities oriented to the application of real laboratories or virtual labs in the form of demonstrations or practicums can provide meaningful learning experiences, gain and enrich conceptual understanding and develop practical skills [11,12]. Implementation of laboratory activities at various levels of education has become a demand that educators must be designed and educated because of the many benefits students will gain [13,14].

However, the facts on the ground do not match expectations. This is due to the fact that laboratory activities are still a constraint for teachers with a variety of reasons including the limitations of available tools; the time taken for the old practicum while the demands and burdens of the material to be taught are numerous; not yet integrated in lab activities with classroom learning; students are only required to prove the results obtained by those contained in the reference; students are rarely asked to submit a prediction and analyze the results obtained. Such laboratory activity is less trembling and awakens the students' thinking and curiosity skills [15].

Based on the problems described previously need to develop a model that can train and develop critical thinking thinking skills in problem solving. The HOT-Lab model is offered as a solution that can train and develop high-level thinking skills. This mode is developed from the problem solving laboratory, where there are various alternative options in the context of real world problem proposed to be solved by the students and there is a presentation activity about the practicum results in front of the class to be discussed with other groups and the lecturers do feedback on the discussion result from the presentation activity.

Woolnougha and Allsop [16] state that there are at least four reasons of the importance of laboratory practice activities. First, the practice can generate motivation to learn science. Second, lab experiment can develop basic skills, such as observing, estimating, measuring and manipulating the variables of inquiry. Third, the practice is a bridge to learn how to use a scientific approach. Through scientific approach, learners can learn to uncover the object observed. Fourth, the practice can support the mastery of the subject matter discussed in the learning process.

Many researchers have defined and considered that Critical Thinking Skills (CTS) are important. According to Ennis [17], CTS is the ability of reasoning, thinking reflectively, and focusing on deciding what to do or what to believe. Critical thinking is a metacognition process that it requires individuals to be able to reflect their thinking process [18]. CTS include the skills to examine, reflect, express arguments and reason logically, determine and evaluate ideas as a result of scientific study [19]. The 21st century most needed ability in the scope of Science, Technology, Engineering, and Mathematics (STEM) works is critical thinking [20]. Various empirical studies aimed at enhancing CTS have been done before. The research was conducted in the classroom as using problem-based approaches [21], science writing heuristic [22], collaborative work approach [23], and guided inquiry learning model [24]. This study aims to determine whether HOT-Lab model can improve student CTS? The research method used quasi experiment with pretest-posttest control group design. The results showed that the use of HOT-Lab model can improve student's CTS.
2. Methods
The method used in this study was quasi-experiment method. The design used was control group pretest-posttest design. Before being treated differently, both groups were given a pretest. Then the experimental group was treated in the form of applied HOT Lab model while the control group using laboratory verification model. After given the treatment, both groups were then given the posttest.

Subjects in this study were students of Physics Education UIN Sunan Gunung Djati Bandung. The sample used in this study was 60 students divided into groups using the HOT-Lab model (30 students) and the group applied the lab verification model (30 students).

Groups using the HOT Lab model in practicum relating to the topic of the RLC circuit, consisting of three sessions: first pre-lab sessions (understanding real world problems, defining and evaluating ideas, answering experimental questions, answering conceptual questions, answering predictions); both lab sessions (determining tools and materials: exploring, measuring, processing and analyzing data, drawing conclusions); third post-lab session (make a presentation). While the control group used a design verification laboratory consisting of 9 stages of activity including: setting goals; provide basic theory; providing tools and materials; answer the original task; perform a predetermined trial procedure; measurements, process and analyze data, draw conclusions, and answer the final task.

The instrument used in this study is an essay test, to measure critical thinking skills associated with the topic of the RLC circuit. The developed Critical Thinking Skills (CTS) indicators adapted from the Binkley et al. Framework [25], which comprise aspects of CTS 1 Explain; CTS 2 Analyze; CTS 3 Interpreting; CTS 4 Synthesizing; CTS 5 inference; and CTS 6 Evaluate.

The enhancement of CTS used gain score \( <g> \) according to Hake [26]. The calculation result of gain \( <g> \) score was then interpreted by the Hake criterion [26]; \( <g> < 0.3 \) (low); \( 0.3 \leq <g> \leq 0.7 \) (moderate); and \( <g> > 0.7 \) (high). The average difference in the improvement of critical thinking ability between the experimental group and the control group was calculated and the statistical tests were performed in accordance with the data obtained. In addition, the calculation of the effect size to determine the effect of HOT Lab model implementation on improving students' critical thinking skills. The effect size of this study was determined by computing the standardized difference (d) according to Cohen [27]. The calculation results were then correlated with the criteria made by Cohen [27] that is; \( 0 < d \leq 0.2 \) (small effect); \( 0.2 < d \leq 0.8 \) (medium effect); and \( d \geq 0.8 \) (large effect).

3. Result and Discussion
The improvement of students' critical thinking skills is indicated by the average calculation result \( <g> \), and then interpreted according to Hake. N-gain critical thinking skills for groups using the HOT-Lab model and groups applying the lab verification model are shown in Table 1.

| Description        | Experiment Group | Control Group |
|--------------------|------------------|---------------|
|                    | Pretest | Posttest | Pretest | Posttest |
| Maximum score (%)  | 41.67   | 81.81   | 33.33   | 55.56    |
| Minimum score (%)  | 25.00   | 69.44   | 16.67   | 36.11    |
| Average score (%)  | 30.37   | 88.89   | 25.28   | 47.22    |
| Standard deviation | 1.72    | 1.75    | 2.04    | 1.78     |
| Gain (%)           | 50.28   |         | 21.94   |          |
| N-gain (%)         | 72.42   |         | 29.34   |          |

Students' critical thinking skills (CTS) in both groups increased. The mean \( <g> \) CTS in the group using the HOT Lab model (72.42%) was categorized as higher than in the group applied by the lab verification model (29.34%) including the low category. The calculation of \( <g> \) each aspect of CTS in both groups is shown in Figure 1.
Figure 1. Average N-gain scores of each aspect of Critical Thinking Skills (CTS)

Students' critical thinking skills in all aspects improved in both groups. Groups using the HOT Lab model experienced a higher increase than the group that applied the lab verification. In groups using the HOT lab model, all aspects of CTS experienced a high categorized increase. Improved critical thinking skills in groups that apply the verification labs of three moderately categorized aspects (CTS 1, CTS 2 and CTS 6), while the other three aspects are categorized as low (CTS 3, CTS 4 and CTS 5).

The increased aspects of CTS 3 included the lowest compared to other CTS aspects in both groups. Increased aspects of CTS 3 students in the group using the HOT Lab model was higher (high category) than the students in the group who applied the lab verification (low category). The activity of processing and analyzing data in the HOT Lab model provides a better opportunity for students to interpret the results of the practicum obtained with the help of ICT. The CTS 2 aspect in the control group was less developed because the students processed and analyzed the results of the laboratory manual. These results support the results of previous studies, which indicate that preservice science teachers have difficulty in interpreting the graphs from practicum data [28].

Students in the group using the HOT Lab model and the group applying the lab verification experienced the greatest improvement in the CTS aspect 1. The explaining aspect was developed in the HOT Lab model on exploration and presentation activities. Students on exploration activities determine the set of tools to be used in measurement activities, experiment variables, data types to collect, table forms for tabulation of data, and steps for practicum activities. In the presentation activity, students present the results of the lab activities in groups. Students applying the lab verification model are told what to measure, perform the prescribed procedure, and do not present the results of the experiments obtained. It is less able to trace aspects of CTS 1 (explain). This is in accordance with the competency focus developed on the verification laboratory model to explain and support what students learn, teach experimental techniques, and poorly train reasoning skills [29,30].

Data distribution of pretest and posttest normality test on students' critical thinking ability in experimental group and control group was done by using Test of One Samples Kolmogorov-Smirnov. The results show that the pretest result data in the experimental group is normally distributed on the significance of 0.309 and 0.072 in the posttest. While the control group has a normal distribution of data on the significance of 0.199 from pretest and 0.130 of posttest. The result of homogeneity test of variance shows that the data in both homogeneous groups in the significance of 0.060. Furthermore, the parametric statistical test (t-test with $\alpha = 0.05$) with the Independent Sample Test showed that the application of HOT Lab model was able to improve students' critical thinking ability significantly compared to the lab verification. It is based on calculation level of significance (2-tailed) 0.000 with $\alpha = 0.05$.

The result of measurement of effect size showed value 3.29. According to Cohen's criterion [27], it is considered to have great effects. Thus, the use of the HOT Lab model provides a great effect in
improving students' critical thinking skills. These results reinforce previous research that the HOT Lab model provides a great influence in improving students' critical thinking skills related to other topics of the transformer [31].

The HOT Lab model is oriented to train and develop critical thinking skills and creative thinking in problem solving through practicum activities. This model is a development of laboratory problem solving, with the characteristics of adding an alternative of answers to real-world problems that are not trivial and add the presentation activity after completing the practicum [32,33]. Laboratory verification model was less able to develop students’ critical thinking skills because they only practice low-level thinking skills. This is consistent with Heuvelen [34] that explains that the application of laboratory verification is of no benefit to students, especially to provide science skills, hands-on skills, and even mind-on skills.

4. Conclusion
In general, we have successfully examined the use of the HOT Lab model in enhancing students' critical thinking skills. The enhancing of students' critical thinking ability using the HOT Lab model is higher than that of students applying the lab verification model related to RLC circuit topics. Therefore, the use of HOT Lab is worth considering to be applied in the implementation of physics lab in other topics

5. References
[1] Denicolo P and Reevers J 2013 Developing transferable skills: enhancing your research and employment potential (London: SAGE Publications Ltd)
[2] Kyllonen P C 2012 Measurement of 21st century skills within the common core state standards Invitational Research Symposium on Technology Enhanced Assessments P21 Framework Definitions
[3] Malik A and Setiawan A 2016 The development of higher order thinking laboratory to improve transferable skills of students Proceedings of the 2015 International Conference on Innovation in Engineering and Vocational Education 56 36-40
[4] Trilling B and Fadel C 2009 21st Century Skills: Learning for Life in Our Times (San Francisco: John Wiley & Sons, Inc)
[5] Alismail H A and McGuire P 2015 21st Century Standards and Curriculum: Current Research and Practice Journal of Education and Practice 6 6 150–155
[6] Jackson D 2014 Business graduate performance in oral communication skills and strategies for improvement The International Journal of Management Education 12 1 22-34
[7] Boyles T 2012 21st Century knowledge, skills, abilities and entrepreneurial competencies: a model for undergraduate entrepreneurship education Journal of Entrepreneurship Education 15 41-55
[8] Griffin P, Care E and McGaw B 2012 The Changing Role of Education and Schools (Assessment and Teaching of 21st Century Skills) eds Griffin P McGaw B and Care E (New York: Springer)
[9] Darling-Hammond L 2012 Policy Frameworks for New Assessments (Assessment and Teaching of 21st Century Skills) eds Griffin P McGaw B and Care E (New York: Springer)
[10] Pacific Policy Research Center 2010 21st Century Skills for Students and Teachers (Honolulu: Kamehameha Schools, Research & Evaluation Division)
[11] Byers W 2002 Promoting active learning through small group laboratory group University Chemistry Education 6 28–34
[12] Kirschner P A and Meester M A M 1988 The laboratory in higher science education: problems, premises, and objectives Higher Education 17 81–98
[13] Wenning C J 2006 A framework for teaching the nature of science Journal of Physics Teacher Education Online 3 3 3-10
[14] Hofstein A and Lunetta V N 2004 The laboratory in science education: Foundation for the 21st century Science Education 88 1 28–54
Acknowledgments

The researcher would like to thank the students and laboratory assistant of Physics Education Study Program UIN Sunan Gunung Djati Bandung, which has assisted in the implementation of research.