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To cite this article: A Setiawan et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 306 012008

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Effect of Higher Order Thinking Laboratory on the Improvement of Critical and Creative Thinking Skills

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Abstract. This research was based on the need for improving critical and creative thinking skills of student in the 21-st century. In this research, we have implemented HOT-Lab model for topic of force. The model was characterized by problem solving and higher order thinking development through real laboratory activities. This research used a quasy experiment method with pre-test post-test control group design. Samples of this research were 60 students of Physics Education Program of Teacher Education Institution in Bandung. The samples were divided into 2 classes, experiment class (HOT-lab model) and control class (verification lab model). Research instruments were essay tests for creative and critical thinking skills measurements. The results revealed that both the models have improved student’s creative and critical thinking skills. However, the improvement of the experiment class was significantly higher than that of the control class, as indicated by the average of normalized gains (N-gain) for critical thinking skills of 60.18 and 29.30 and for creative thinking skills of 70.71 and 29.40, respectively for the experimental class and the control class. In addition, there is no significant correlation between the improvement of critical thinking skills and creative thinking skills in both the classes.

1. Introduction
The learning achievement described in the National Standards of Higher Education implies that every university needs to equip students with the 21st century skills including critical thinking, creative thinking, problem solving, cooperative, communication as well as ICT-literate. Those skills are well known as 21st century skills or transferable skills. In general, transferable skills are skills developed in one situation to be transferred to other situations, from classroom learning situations to real life situations [1].

Transferable skills can be developed through science learning process in classrooms or practicum in laboratories. Practicum is important to (1) generate motivation for science learning, (2) improve basic skills of experiment, (3) apply scientific approach and (4) support mastery of learning materials [2]. The main purpose of physics practicum is to increase physics knowledges, improve practicum skills, aroush interest, develop creative thinking and problem-solving skills, improve scientific thinking skills as well as apply methods of experiment [3]. In addition, practicum also offers context-rich learning experiences, enhance conceptual understanding, develop practical skills [4] and the best way to learn the nature of science [5, 6].

In fact, purposes of practicum as mentioned above have not fully implemented by teachers in physics teaching and learning as reflected in the results of questionnaires distributed to several senior high schools in West Java. Most physics teachers face difficulties to develop practicum procedures. The current practicums tend to cookbook model and lack of practicum equipments. Most physics teachers
only organize practicum twice per semester [7]. A research reported that implementation of physics practicum in senior high school in Bengkulu Province is in the low category [8]. Main constrains experienced by teachers to do practicum are as follow: (1) lack of practicum facilities, (2) time limited to do practicum and (3) difficult to design practicum. We also identified that the existing practicums havenot developed higher order thinking skills. By considering the previous findings, it is urgent to develop a Higher Order Thinking Laboratory (HOT Lab) to facilitate 21st century skills (transferable skills). Furthermore, the HOT Lab developed in this research should be able to solve problem with practicum equipments and limited time for practicum.

Some empirical studies aimed at improving critical and creative thinking skills as part of transferable skills has been widely carried out. Research on strategy and model of learning to enhance critical thinking skills that have been done include guided inquiry learning model [9], problem-based approach [10], collaborative work approach [11], application of writing strategies [12]. Research on improving creative thinking skills using strategies and learning models that have been done include brainstorming [13, 14], lateral thinking [15], creative problem solving [16, 17], project-based learning [18] and creative inquiry learning [19]. While research on the improvement of two high-level thinking skills, critical and creative thinking skills together through practicum in university level is as an innovation. Therefore this research addresses what can the HOT lab improve critical and creative thinking skills and what is the relationship between students' critical and creative thinking skills.

2. Experimental Method
This research employs a quasi-experimental method with control group pretest-posttest design. The experiment class implemented HOT Lab consisting of 11 stages: real world problem, determine and evaluate ideas, experimental questions, materials and equipment, prediction, question method; exploration, measurement, analysis, conclusion and presentation. While the control class implemented verification lab consisting of 9 stages: objectives, basic theory, tools and materials, preliminary assignment, trial procedure, measurement, analysis, conclusion, and final report.

Population in this research is students of Physics Education Program of UIN Sunan Gunung Djati Bandung at semester IV in academic year of 2015/2016. The samples are 60 students divided into 30 students for experimental class and 30 students for control class. The samples were selected by using a simple random sampling technique. The instrument used in this research is an essay test to measure critical and creative thinking skills on the concept of Force. Indicators of critical thinking test refers to Binkley et all framework [20], while indicator of creative thinking skills test refers to Torrance framework.

Data were analyzed by using a normalized gain <g> according to the equation expressed by Hake [21]. The calculated <g> was then interpreted by the Hake criterion [22] (<g> < 0.3 (low); 0.3 ≤ <g> ≤ 0.7 (medium); and <g> > 0.7 (high)). The difference of the <g> for experiment and control classes was tested by t-test after previously conducting normality test using One-Sample Kolmogorov Smirnov test and homogeneity test by using test of homogeneity of variances. Then, correlation between critical thinking skill and creative skills was calculated by correlation bivariate test.

3. Result and Discussion
3.1. Critical Thinking Skills
Figure 1 provides average score of pretest, posttest and N-gain for creative thinking skills. N-gain of critical thinking skills for HOT Lab class is 60.2% (medium category) and verification lab class is 29.30% (low category). Result of statistical calculation is shown in Table 1. It can be concluded that there is a significant difference of students' critical thinking skills skill between HOT lab class compared to lab verification class. This means that HOT lab is better than verification lab to improve critical thinking skills.
Figure 1. Average N-gain scores of critical thinking skills

Table 1. Statistic calculation of critical thinking skills data

<table>
<thead>
<tr>
<th>Data type</th>
<th>Normality (α = 0.05)</th>
<th>Homogeneity (α = 0.05)</th>
<th>Uji t (α = 0.05)</th>
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<td>Information</td>
<td>Level Significance (2-tailed)</td>
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<td>Critical thinking skills</td>
<td>Experimental</td>
<td>Control</td>
<td>Experimental</td>
</tr>
<tr>
<td>N-gain of critical thinking skills</td>
<td>0.782</td>
<td>0.983</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Further calculations are performed for each aspect of critical thinking skills in both the groups. The result is shown in Figure 2. The N-gain for each aspect of critical thinking skills in the experimental class is higher than the control class. All aspects of critical thinking skills (CTS1 to CTS6) in the experimental class are in medium category. The N-gain of critical thinking skills aspect in the control class classified into two categories, namely medium category for CTS1 and CTS2 and low category for CTS3 to CTS6.

Figure 2. Average N-gain for each aspect of critical thinking skills

Respectively:
1. CTS1. Explain. State results, justify procedures, and present arguments
2. CTS2. Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems
3. CTS3. Interpret information and draw conclusions based on the best analysis
4. CTS4. Synthesize and make connections between information and arguments
5. CTS5. Inference. Query evidence, conjecture alternatives, and draw conclusions
6. CTS6. Evaluate. Assess claims and arguments
The CTS1 aspect shows the greatest N-gain for both the class, in medium category. However, the experimental class shows higher improvement than the control class. The aspect of explanation shows the greatest N-gain in both the classes. Students of the HOT Lab class are capable to present and provide results, procedures and arguments. Those skills have been developed in the stage of exploration and presentation in the HOT Lab design. In the both stages, the students design and check system of work from provided choice of answers to solve problems and present experimental results obtained in the form of verbal and non-verbal. In contrast, students of verification lab class are already informed what to measure, perform the given procedures. They do not present the the obtained experiments. This result agreed with previous study that cookbook experiments less facilitates to know what have been done during the experiment [22].

Aspect of CTS4 shows the smallest N-gain in both the classes. But, the experiment class has higher N-gain (medium category) compared ro the control class (low category). Stages of experimental questioning and questions method in the HOT lab design facilitate much better opportunity for students to connect the provided information with the presented arguments. While the student of verification lab class only decide the details of the analysis and emphasize the concept comprehension (quantitative). This is in accordance with the focus of developed competency in the lab verification design that supports what students are learning, teaching experimental techniques but lacking the practice of thinking skills [23].

3.2. Creative thinking skills

Figure 3 provide the average score of pretest, posttest and N-gain of creative thinking skills for the experimental class and control class on the topic of force. Here, N-gain scores are provided in decimal numbers. We noted that creative thinking skills of the experimental class and the control class are increased. However, N-gain of the experimental class is higher (0.7, high category) than that of the control class (0.29, low category). Table 2 provides results of statistical calculation of creative thinking skills in experiment and control class. It can be concluded that there critical thinking skills of the experimentaklass (HOT lab class) is significantly better than that of the control class (Verification Lab class).

![Figure 3. Average N-gain of creative thinking skills](image)

<table>
<thead>
<tr>
<th>Data type</th>
<th>Normality (α = 0.05)</th>
<th>Homogeneity (α = 0.05)</th>
<th>Uji t (α = 0.05)</th>
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<td></td>
<td>Level</td>
<td>Information</td>
<td>Level</td>
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<tr>
<td>Creative thinking skills</td>
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<td>Control 0.509</td>
<td>Homogeneous 0.798</td>
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<tr>
<td></td>
<td>Control Normal</td>
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Table 2. Statistic calculation of students’ creative thinking skill
Further calculations have been made for each aspect of creative thinking skills in both the classes (Figure 4). The average N-gain for each aspect of creative thinking skills in the experimental class is higher than that of the control class. In the experimental class, three aspects of creative thinking skills (fluency, flexibility and elaboration) showed high category while the aspect of originalities showed medium category. The N-gain aspects of creative thinking skills in the control class classified into two categories: fluency and elaboration are in the medium category while the flexibility and originality aspects are in low category.

![Figure 4. Average N-gain for each aspect of creative thinking skills](image)

Fluency aspect shows the greatest N-gain both in the experimental class and control class. N-gain of the experimental class is higher than the control class. In the stages of question method, activity in the HOT lab design provides a better opportunity for students to think fluently related to asking questions that serve a guide for a problem solving. One can find the most basic principles of physics and its problems by asking questions [24]. The fluency aspect in the control group is less developed, because in the verification lab design students are just doing the procedures already given. This agrees with other report that the implementation of verification lab rarely facilitate to understand what has been done [25].

The originality aspect shows the smallest N-gain for both the experimental class and control class. N-gain of the experimental class is higher than the control class. The stages of exploration and analysis activities in the HOT lab design give better opportunities for students to think originaly to produce a new and unique phrase. In contrass, students who implemented verification lab design only decide the details of analysis and emphasize the concept comprehension. The results are similar to other studies repoting that the application of CPS strategy as the basis of HOT Lab design does not significantly improve originality of thinking skills as compared to non-CPS strategies [26].

### 3.3. Correlation between creative and critical thinking skills

In this study, we also explore the correlation between N-gain of critical thinking skills and creative thinking skills in the experimental class and control class. The result of statistical calculation is provided in Table 3. We found that significantly there is no correlation between N-gain of critical thinking skills and N-gain of creative thinking skills both for experimental class and control class. The result indicate that critical thinking skills and creative thinking skills as high-level thinking skills are associated with other variables such as age, cognitive level and field of study[27]. Other aspect related to the science process is the logic of science as a form of logical thinking. Therefore, the laboratory activities also give a rich context for using logical thinking together between creative thinking skills and critical thinking skills [28]. Every activity in the HOT Lab promotes together convergent thinking (critical thinking) and divergent thinking (creative thinking).
Table 3. Correlation between creative thinking and critical thinking skills of the experimental class and control class

<table>
<thead>
<tr>
<th>Group</th>
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<tr>
<td></td>
<td>Critical</td>
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<td>Level of Significance</td>
</tr>
<tr>
<td>Experiment class</td>
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<td>0.528</td>
<td>Normal</td>
</tr>
<tr>
<td>Control class</td>
<td>0.983</td>
<td>0.509</td>
<td>Normal</td>
</tr>
</tbody>
</table>

4. Conclusion

We have successfully carried out a research to investigate effect of HOT lab in improving critical thinking skills and creative thinking skills of students. The results showed that HOT lab increased better critical thinking and creative thinking skills of students as compared to verification lab design. This research also found that there is no significant correlation between improvement of creative thinking skills and critical thinking skills. However, further researchs are required to elaborate factors that influence no-correlation between critical thinking skills and creative thinking skills.

Acknowledgments

The authors would like to thank to the chairperson, Lab operator and assistant as well as students of the Program Studi Pendidikan Fisika UIN Sunan Gunung Djati Bandung who allowed and contributed in this research. The authors also would like to thank The Ministry of Research, Technology and Higher Education for financial support of this research through Hibah Pascasarjana research scheme year 2017.

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