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Enhancing Pre-Service Physics Teachers' Creative Thinking Skills through HOT Lab Design

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Abstract. A research on the implementation of HOT (Higher Order Thinking) Laboratory has been carried out. This research is aimed to compare increasing of creative thinking skills of pre-service physics teachers who receive physics lesson with HOT Lab and with verification lab for the topic of electric circuit. This research used a quasi-experiment methods with control group pretest-posttest design. The subject of the research is 40 Physics Education pre-service physics teachers of UIN Sunan Gunung Djati Bandung. Research samples were selected by class random sampling technique. Data on pre-service physics teachers' creative thinking skills were collected using test of creative thinking skills in the form of essay. The results of the research reveal that average of N-gain of creative thinking skills are <0,69> for pre-service physics teachers who received lesson with HOT Lab design and <0,39> for pre-service physics teachers who received lesson with verification lab, respectively. Therefore, we conclude that application of HOT Lab design is more effective to increase creative thinking skills in the lesson of electric circuit.

INTRODUCTION

The pace of technological development and the information very rapidly in the 21st century is affecting a paradigm shift in the world of education in addressing the challenges of the 21st century. Educational paradigm is currently focusing on preparing students to have the readiness to work and have 21st century skills to face the challenges of the 21st century [1].

Higher education should consider few things related to preparing its students in facing the internal and external challenges. The internal challenge is the demand to fit the national education standards. The external challenge is the globalization with the implementation of ASEAN Economic Community, CAFTA, APEC, WTO; environmental issues; the ICT development; the convergence of science and technology; science-based economy; the rise of creative economy and culture; the shifting of world economic power; the influence and the effect of technoscience; quality, investigation, and transformation of education sector [2].

All these things above is in line with the demand of learning objectives expected from the implementation of National Qualification Framework of Indonesia (KKNI) in the knowledge aspects, attitudes, and the specially skilled works. Thus, higher education should prepare its students with various skills to face the challenges in above and to

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face the 21st century. One of the skills needed to be trained and developed regarding competition in the 21st century is transferrable skills.

Some terms that refer to the transferable skills that are used in various countries include life-oriented, work-oriented, life skills, 21st-century skills, global competence, soft skills, crosscutting skills, generic skills, transversal skills, non-cognitive skills, cross-curricula skills, employability skills, core skills, and key skills. There are differences and conceptual understanding of transferable skills in different countries but in general, transferable skills refers to some important competencies that can be learned and needed by everyone to have a chance of success, become leaders and productive in his life [2].

Given the importance of the development of transferable skills, the teaching of physics should be appropriate to the 21st century educational paradigm that provides a space for students to develop these skills. Instructional design which is in line with the needs of the 21st century has the following special characteristics: 1) use innovative instructional strategies to use modern technology as a medium of learning, 2) integration of cognitive and social abilities with the content of teaching, and 3) give priority to the active participation of the students [3]. Some studies that explain the need to develop transferable skills have been carried out [4-8].

Based on the analysis of a variety of research that learning needed constructivism activities are oriented to solve the problem, active learning in developing the ability to think and engage in collaborative working can facilitate students to improve transferable skills. One of the learning activities that meet these criteria is practical.

Practicum is the practice at the laboratory including demonstrations, computer simulations complement experiments work on hand, offering to students a rich learning experience, gain a conceptual understanding of disciplines and develop practical skills [9, 10]. Practicum has advantages such as: 1) to increase knowledge of the concepts of physics, 2) develop skills of practical, 3) increase the interest of students, 4) develop creative thinking skills and problem-solving skills, and 5) facilitating the development of the thought processes of science and science process skills [11]. However, not all types are considered effective practical design to implement. Design verification lab as an example, a lot of criticism because only oriented towards mastery of concepts only. Based on the results of the study [12] that the results of the experimental application of the cookbook rarely demonstrate an understanding of what is being implemented.

There is a need to provide practicum that can train transferable skills, furthermore developed the design of HOT Lab [2]. HOT stages in the lab are the result of a merger between CPS (Creative Problem Solving) and PSL (Problem Solving Laboratory). From the merger of these two models, the steps of the HOT Lab are composed of five general proces: 1) understand the challenges given, 2) produce ideas, 3) prepare practical activities, 4) carry out practical activities, and 5) communicate and evaluate the results of activities [2]. Any activity in HOT Lab promotes both convergent thinking skills and divergent thinking (creative thinking).

Many researchers have defined and identified important creative thinking skills. Creative thinking skill is one of the ways of thinking that takes a person in working life and society in the 21st century [13]. According Stojanova [14] creativity is the process of cognitive psychology in which the process is defined as a way to get the creative product. Creativity is an important factor in maintaining the existence and developing the existing culture and industry [15]. As well as critical thinking skills, creative thinking skills are required in the problem solving process [16]. In addition, in an environment that demands collaborative activity, having the critical thinking skills is not enough as capital in activities if it is not completed with a mastery of creative thinking skills [17].

Various empirical researches that aim to improve creative thinking skills as part of the transferable skills have been widely implemented. Creative thinking skills enhancement research using a variety of strategies and learning models such as brainstorming [18, 19, 20], lateral thinking [21], creative problem solving [22, 23], project-based learning [24], and creative inquiry learning [25].

Research on improving creative thinking skills through practicum and implemented the college considered as a new innovation. Hofstein and Lunetta [26] states that there are at least four reasons the importance of practical activities, namely: 1) practicum can evoke motivation to learn science, 2) practicum can develop basic skills to experiment, (3) practicum as a vehicle for learning to apply the scientific approach, 4) practice to support the mastery of learning materials. The main objective is to increase knowledge of physics lab physics; develop practical abilities; generate interest, develop creative thinking and problem solving skills; improve scientific thinking skills and provide practice in the experimental method [27]. Practicum also offers a context rich learning experience, improve conceptual understanding, develop practical skills [9, 10], and is the best way to reflect on the nature of science [28, 29]. Various practicum purposes above have not been fully implemented educators in teaching physics.

METHOD

The method used in this study is a quasi-experimental method with control group pretest-posttest design. Firstly, the experimental group and the control group were given pretest then the experimental group was given treatment in the form of application HOT Lab design while the control group applied lab verification design. After being given the treatment, the two groups were then given posttest.

Experiment group in doing practical work on the electrical circuit using HOT Lab design consisting of 11 phases of activities which include: real world problems; determine and evaluate ideas; experimental question; materials and equipment; prediction; question of the method; exploration; measurement; analysis; conclusion; and presentations. While the control group using verification lab design that consists of 9 phases of activities which include: purpose; basic theory; tools and materials; preliminary tasks; laboratory procedures; measurement; analysis; conclusion; and end tasks.

The population in this study was all students Prodi Pendidikan Fisika UIN Sunan Gunung Djati Bandung class in 2015. The samples used in this study were 40 students consisting of 20 students of the experimental group and 20 students of the control group. The samples were choosed by using simple random sampling technique.

The instrument used in this study is a test creative thinking skills in essay form. Creative thinking skills test includes aspects of fluency, flexibility, elaboration and originality. To find creative thinking skills improvement, calculating the gain normalized <g>. The equation to calculate the average gain normalized <g> is presented in Equation (1) [30]

$$< g >= \frac{< S_{post} > - < S_{pre} >}{< S_{maks} > - < S_{pre} >} \quad (1)$$

The calculation result <g> is furthermore interpreted by the criteria Hake [30] namely; <G> < 0.3 (low); 0.3 ≤ <g> ≤ 0.7 (moderate); and <g> > 0.7 (high). To test whether there are differences in the average increase creative thinking skills between the experimental group and control group, test the average difference (t-test), which previously carried out test for normality using the One-Sample Kolmogorov-Smirnov test and homogeneity test using the Test of Homogenity of Variances. In addition, to determine the impact of the adoption of this HOT Lab design to increase creative thinking skills of students relative to the application of verification lab design, then performed the calculation of effect size. To find effect size, calculating the standardized mean difference. The equation to calculate the standardized mean difference (d) is presented in Equation (2) [31].

$$d = \frac{M_1 - M_2}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}} \quad (2)$$

Results of the calculations then correlated with the criteria established by Cohen [31], namely; 0 <d <0.2 (small effect); 0.2 ≤ d ≤ 0.8 (medium effect); and d ≥ 0.8 (large effect).

RESULTS AND DISCUSSION

The improvement in students' creative thinking skills is shown by calculating the individual N-gain <g> then averaged and interpreted into the N-gain category. The data needed to calculate the magnitude of the increase in understanding is the pretest and posttest result data for the experimental and control groups. N-gain creative thinking skills for the experimental and control groups can be seen in Table 1.

TABLE 1. Score of pretest, posttest, N-gain creative thinking skills in experimental and control groups

Description	Experimental group		Control group	
	Pretest	***Posttest***	***Pretest***	***Posttest***
Maximum score	5	8	5	8
Minimum score	3	6	2	4
Avarage score	3.80	7.40	3.45	5.6
Standard deviation	0.77	0.60	0.76	1.05
Gain	3.6		2.15	
N-gain	0.69		0.39	

Table 1 shows that the scores of creative thinking skills for both groups are equally elevated. The average gain in students' creative thinking skills for the experimental group is 3.6 whereas the gain for the control group is 2.15. Based on the calculation result, the average score of <g> students creative thinking skill in the experimental group is 0.69, including the medium category is higher than the control group of 0.39, including the medium category.

To sharpen the analysis, further calculations are performed for each indicator of creative thinking skills in both groups. The calculation results are shown in Fig 1.

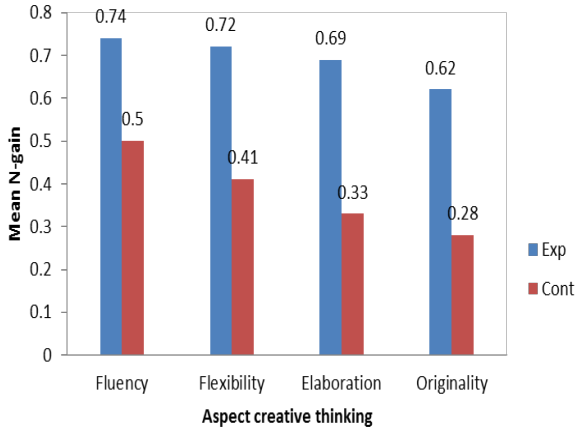

FIGURE 1. The average N-gain every aspect of creative thinking skills

Figure 1 shows that students' creative thinking skills on the aspects of fluency and flexibility for both groups are equally increasing. The improvement of creative thinking skills in these two aspects in the experimental group is higher than the control group. The improvement of the two aspects of creative thinking skills in the experimental group was in the high category, while for the control group included in the medium category.

The students' creative thinking skill on the aspect of elaboration in both groups experienced an improvement as shown in Fig 1. The improvement of creative thinking skills in this aspect in the experimental group is higher than the control group. The improvement of the aspect of elaboration in both groups was in the medium category.

Figure 1 shows that students' creative thinking skills on the aspects of the originality for both groups are equally increasing. However, the improvement of the originality aspect in the experimental group included in the moderate category, while for the control group included in the low category.

The fluency aspect experienced is the highest increase in N-gain in both experiment and control groups. Students in the experimental group experienced a higher increase than students in the control group. The stages of the question activity method in the HOT Lab design provide a better opportunity for students to think smoothly related to asking many questions that serve as a guide in solving a problem. The fluency aspect in the control group is less likely to develop, because students do what is specified in the lab verification design procedure. Someone can find the most basic fundamental principles of physics and its problems by asking many questions [32]. This reinforces the results of previous studies by Von Aufschnaiter, C. & Von Aufschnaiter, S [12] that the application of cookbook experiments rarely shows an understanding of what had done.

Aspects of flexibility in the experimental group experienced a greater improvement than in the control group. Students who apply the HOT Lab design may propose a variety of ideas, answers, or questions that vary with the guessing activity for an event. It is developed at the stage of determining and evaluating ideas in the HOT Lab design. While students' who apply design lab verification must obey a predetermined procedure. The results of this study reinforce the results of previous studies [32-34] which found that the CPS strategy could further improve students' creative thinking skills on the aspects of fluency and flexibility when compared with non-CP or conventional strategies. This is appropriate with the HOT Lab design characteristics developed from the CPS learning model.

The elaboration aspect in the experimental group experienced has a better improvement than in the control group. Students who apply HOT Lab design can enrich and develop an idea or product by improving the output. It is developed at the exploration activity stage in HOT Lab design. The competitiveness of a nation is determined by the creativity of its human resources, so the elaboration aspect needs to be developed. Thus creativity is necessary to develop science and technology [36]. The elaboration aspect of the control group is less developed because students are known what to measure and determine how to make measurements. This is consistent with the focus on design competencies developed that describes the lab verification and support what students are learning, teaching experimental techniques and less training thinking skills [37].

The originality aspect experienced the smallest increase in N-gain this occurs both in experimental and control groups. Students in the experimental group experienced a higher increase than students in the control group. The stages of exploration and analysis activities in the HOT lab design provide a better opportunity for students to think originality related to being able to create a new and unique phrase. Students applying lab verification designs only decide the details of analysis and emphasis on the concept (quantitative). The results of this study are similar to those of Wang [32] which show that the application of CPS strategy as the basis for HOT Lab design development does not significantly improve the students' originality of thinking skills compared to non-CP strategies.

The normality test of the distribution of pretest and posttest data of students' creative thinking skill in the experimental group and control group was performed using One-Sample Kolmogorov Smirnov Test. The results show that the pretest and posttest in the experimental group obtained the result that the data is normally distributed at a significance of 0.160 for pretest and 0.06 for posttest. Similarly, in the control group that the normal distribution of data on the significance of each 0.119 and 0.394 for the pretest and posttest. The homogeneity test of students' creative thinking skill in the experimental group and control group has calculated by using Test of Homogeneity of Variances. The calculation results show that the homogeneous data on the significance of 0.850. Furthermore, parametric statistic test (t-test with $\alpha = 0,05$) with Independent Sample Test result showed that the application of HOT Lab design can significantly improve students' creative thinking skill compared with the application of lab verification design. It is based on the result of t-count = 6,496 which is bigger than t-table = 2.025.

The results showed that the effect size for creative thinking skills is 1.65 and based on the Cohen criterion [31], this gain is included in a large effect. Thus it can be concluded that the application of HOT Lab design is effective in improving the creative thinking skill of students with big influence category compared with lab verification design.

HOT Lab design has the characteristics that enable to be able to improve student creative thinking skill. HOT Lab design is a development of the model creative problem solving and model problem solving laboratory [2]. HOT Lab design has the characteristics: it contains a problem that is rich in context and must be solved through a practicum in the lab, the application of the concepts of physics to solve the problem, contain limitations in terms of problem solving, requires creative thinking skills in solving the problem, there are a variety of options alternative answers which are not trivial to solve the problem, and the solving results were presented.

Creative thinking skills of the students in the control group that apply the lab verification design have not improved optimally, because the students must obey the step by step and the provisions contained in the lab manual and should not be different at all. This kind of practice does not develop thinking skills and involves small part the intellectual of students [38]. This is in accordance to Wenning's opinion [35] which said that the lab cookbook has features such as: are driven step by step instructions requiring minimum intellectual involvement thereby promoting robotic, rule-conforming behaviours, assume student will learn the nature of the scientific process by ‘experience’ or implicitly, student execute imposed experimental design; tell which variables to hold constant, which to vary, which are independent, and which dependent.

CONCLUSION

The application of HOT Lab design is more effective on improving creative thinking skills compared to the application of lab verification design on electrical circuit concept. Therefore, the application of HOT Lab design more considering for use in physics learning in other concept, as well as in physics learning in the other formal education level.

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