How to Improve Creative Thinking Skills of Pre-Service Physics Teachers?

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Abstract: The present study was aimed at investigating the use of Higher Order Thinking (HOT) Lab to improve creative thinking skills of pre-service physics teachers. To this end, this study employed a quasi-experimental design. The research subjects were 60 students enrolled in the Physics Education Program of UIN Sunan Gunung Djati Bandung. 30 of them were assigned to the experimental group who used the HOT Lab, and the other 30 to the control group who used verification lab. The results revealed that students' creative thinking skills improved with a high average N-gain as a result of using HOT Lab that consists of various activities that can enhance creative thinking skills. Thus, it can be concluded that the use of HOT Lab can improve students' creative thinking skills better than the use of verification lab. It is recommended that HOT Lab be used in other educational levels.

1 INTRODUCTION

Active learning pedagogies that promote Higher Order Thinking Skills (HOTS) play an important role and are suggested to be implemented in educational system (Alismail and McGuire, 2015; Madhuri et al., 2012). Therefore, a problem solving oriented HOT Lab was developed to develop HOT through practicums (Malik et al., 2012). According to Malik and Setiawan (2016), HOT Lab procedure is a combination of creative problem solving and problem solving lab and consists of five general process: 1) understanding a given challenge, 2) producing ideas, 3) preparing practicum activities, 4) carrying out practicum activities, and 5) communicating and evaluating the outcomes. Every activity in HOT Lab is designed to promote both convergent (critical) and divergent (creative) thinking skills.

Creative thinking skills (CTS) is required to anticipate the opportunities and challenges of the 21st century. As a way of thinking, CTS can be used to work collaboratively to solve problems and to generate and develop innovative products (Chai et al. 2015; Klieger and Sherman, 2015; Chang et al. 2015; Binkley et al. 2012; Stojanova, 2010). Therefore, students' CTS should be trained and developed during the lecture in order for the students to be ready for the future challenges.

There have been many studies on CTS as part of HOTS; for examples, studies on the implementation of creative problem solving strategy to improve CTS by Im et al. (2016) Leisema and Wannapiron (2013) Centikaya (2013) and Wang and Horng (2002). Other studies used various instructional models to improve CTS including: creative inquiry learning (Yang et al., 2016), project-based instruction (Şener et al. 2015), brainstorming (Runco, 2007), creative problem solving (Isaksen and Treffinger, 2004), inquiry based learning (Madhuria et al. 2012). Other studies investigated the correlation between CTS and other aspects such as learning achievement (Anwar et al., 2012), reading and writing skills (Copping, 2016; Wang, 2012). Other studies investigated the effectiveness of using certain instruments or trainings to improve CTS; for example, the effect of using Scientific Structures Creativity Measure (SSCM) on divergent thinking (Meyer and Lederman, 2015), the effect of creative reversal act on creative thinking (Sak and Oz, 2010), and the effectiveness of creativity training (Scott et al, 2004).

However, few studies have investigated the implementation of HOT oriented practicum in universities to improve students' CTS. This study

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employed a quasi-experimental design. An essay test was used to measure the pre-service physics teachers' CTS after using HOT Lab.

2 METHODS

This study used a quasi-experimental design. The experimental group carried out a practicum on elasticity using HOT Lab consisting of 11 activities as follows: understanding real world problem, determining and evaluating ideas, answering experimental questions, preparing materials and instruments, answering predictions, answering methodical questions, exploring, measuring, analyzing, drawing a conclusion, and presenting the outcomes. Using verification lab, the control group carried out a practicum on elasticity consisting of nine activities as follows: understanding the objectives, understanding the basic theory, preparing materials and instruments, completing the introductory task, carrying out the experiment procedure, measuring, analyzing, drawing a conclusion, and completing the final task.

The research subjects were all fourth semester students enrolled in the Physics Education Program of UIN Sunan Gunung Djati Bandung in the 2016-2017 academic year. The samples were 30 students consisting of 12 males and 18 females assigned to the experimental group and 30 control group students consisting of 9 males and 21 females; they were chosen using a simple random sampling technique. The samples were heterogeneous in their achievement index. The population claimed that they did not have sufficient CTS training during the lectures.

Students' CTS was measured using an essay test developed with reference to the Torrance's framework comprising four components: fluency, flexibility, elaboration, and originality. In addition, every test question item was also designed to elicit creative thinking activities such as asking question, guessing of cause, fixing the product, guessing the possibility that happened, and fixing the results; the design was adopted from Alrubaie and Daniel (2014). The scoring system for every question used a 1-3 scale.

To find out the improvement in CTS, a normalized gain <g> calculation was carried out. The result of <g> calculation was interpreted using Hake's (1999) criteria: <g> <0.3 means low, $0.3 \leq$ <g> ≤ 0.7 means moderate, and <g> > 0.7 means high. After the normal distribution and homogeneity tests, a *t*-Test was conducted to find out if the CTS improvement of the experimental group was different from that of the control group.

In addition, to identify the effect of HOT Lab on the CTS improvement, an effect size calculation was conducted. The effect size was identified using the standardized mean (d) from Cohen et al (2007). The result of calculation was interpreted using the criteria from Cohen et al (2007); i.e., $0<d<0.2$ means a small effect, $0.2 \leq d \leq 0.8$ means a medium effect, and $d \geq 0.8$ means a large effect.

3 RESULTS AND DISCUSSION

The CTS improvement size was measured by calculating individual N-gain. Table 1 presents the data of CTS improvement of both experimental and control groups.

Table 1: Students' CTS Improvement.

Category N-Gain KBK	N-gain Average (%)	
	Experimental	Control
Low	0.00	63.33
Medium	13.33	36.67
High	86.67	0.00
Average	73.63	29.76

The majority of experimental group students experienced a high improvement in their CTS, and the majority of control group students experienced a low improvement. The N-gain average score of the experimental group was 73.63%, and that of the control group was 29.76%.

The pretest and posttest average scores of the experimental group were 45.42% and 85.56% respectively, and those of the control group were 33.06% and 52.92%. Table 2 presents the statistical data of CTS improvement of both experimental and control groups.

Table 2: Statistical Data of Students' CTS Improvement.

Data type	Normal distribution test (α= 0.05)				Homogeneity Test (α= 0.05)	*t*-Test	
	Significance level		Note			Significance level	Note
	Experimental	Control	Experimental	Control			
Creative thinking skills	0.112	0.087	Normally distributed	Normally distributed	0.325 Homogeneous	0.000	Significant

Table 2 shows that the data of both groups were normally distributed and homogeneous. The result of *t*-Test showed that the experimental group students' CTS was significantly different from those of the control group students.

The <g> calculation for each CTS indicator was conducted to elaborate the result discussion. Table 3 presents the N-gain average score of each CTS indicator of both groups.

Table 3: N-gain average score of each CTS indicator.

No	Activity of creative thinking skills	Aspect of creative thinking skills							
		Fluency		Flexibility		Elaboration		Originality	
		Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
1	Asking question	0.75	0.28	0.60	0.21				
2	Guessing of cause	0.80	0.24	0.70	0.28				
3	Fixing the product					0.72	0.33	0.72	0.36
4	Guessing the possibility that happened					0.75	0.37		
5	Fixing the results							0.81	0.20
Average		0.78	0.26	0.65	0.25	0.74	0.35	0.77	0.28

Fluency was the most improved aspect in the experimental group. Its improvement was high. However, it was low in the control group. Students who used HOT Lab could think fluently when asking questions and guessing causes. The N-gain average score for the guessing of because activity was higher than that of the asking question. Students were trained to ask questions and guess causes by determining and evaluating ideas, answering predictions, exploring and presenting the outcomes in HOT Lab. Students could think fluently when choosing and analyzing the given ideas to solve real world problem, predicting the cause and effect relationship between variables, exploring and testing ideas to design the experiment procedure, and presenting the outcomes to test the predictions previously proposed collaboratively. The result of this study confirms the result of a previous study that the use of HOT Lab improved students' fluency better than the verification lab (Malik, et al., 2017). The fluency of the control group students who used the verification lab was not well-trained and not well-developed. The N-gain average score of the guessing of because activity was lower than that of the asking question. This indicated a difference from the experimental group. Students only proved what they had previously learned. During the practicum, they had to do something previously determined in the experiment procedure. This confirms a previous study that cookbook experiment does not facilitate understandings of what has been done (Von and Von, 2007).

Flexibility was the least improved aspect in both groups. However, the improvement in flexibility of the experimental group was medium, or higher than that of the control group. Those who used HOT Lab could think flexibly when asking questions and guessing causes by presenting various questions, arguments, and answers to solve the real world problem. The flexibility N-gain average score of the guessing of because activity was higher than that of the asking question. The flexibility in asking questions and guessing causes was trained and developed by answering predictions, answering experimental questions, answering methodical questions, measuring and analyzing during practicum in HOT Lab. This is in agreement with previous studies that CTS can be enhanced through collaborative problem solving (Leisema and Wannapiron, 2013; Centikaya, 2013). The flexibility improvement of the control group was low. The flexibility N-gain average score of the guessing of because activity was higher than that of the asking question. This goes to show a difference from the experimental group in fluency and a similarity in flexibility. Those who used the verification lab could not think flexibly because they were always told what and how to measure by following the predetermined procedure. This is in line with McDermott's (1999) opinion that conventional laboratory activities do not really help improve thinking ability.

The improvement in elaboration of the experimental group was high and higher than that of the control group. Those who used HOT Lab could think elaborately when fixing the product and guessing possibilities by enriching and developing an idea or a product to improve the outcomes. The N-gain average score of the guessing the possibility that happened activity was higher than that of the fixing the product activity. Elaboration aspect was trained and developed when exploring, measuring, analyzing, and presenting the outcomes in HOT Lab. This confirms the result of study conducted by Malik et al. (2017) that HOT Lab could improve the elaboration aspect better than the verification lab. Elaboration was the most improved aspect in the control group. The N-gain average score of the guessing the possibility that happened activity was higher than that of the fixing the product activity. This indicated a similarity to the experimental group. Students who used the verification lab analyzed and determined various factors to see if the outcomes corresponded to the references. This is in line with Heuvelen's (2001) opinion that cookbook lab practicum is no longer beneficial for the students especially when it comes to equipping them with hands-on and minds-on scientific skills.

The improvement in the originality aspect of the experimental group was high and higher than that of the control group. The N-gain average score of the fixing the result activity was higher than that of the fixing the product activity. The activity of answering methodical questions, exploring, measuring, analyzing, and presenting the outcomes in HOT Lab enabled students to think originally during fixing the product and fixing the results activities. Students were able to express new and unique ideas to solve a problem and to produce an innovative product. This is in contradiction with the result of a previous study suggesting that implementing creative problem solving (CPS) strategy as a basis for the development of HOT Lab is not significantly better than non-CPS strategies in improving students' original thinking (Wang and Horng, 2002). Originality aspect of the control group students in fixing the product and fixing the results activities was not well-trained and not well-developed. The N-gain average score of the fixing the result activity was lower than that of the fixing the product activity. This result indicated a difference from the experimental group. The control group students simply decided the details of the analysis with an emphasis on conceptual (quantitative) proof. The main objective of verification lab is to describe and elaborate what has been learned and to teach an experimental technique (Heller, K and Heller, P, 2010).

The improvements of all CTS aspects of the experimental students were higher than those of the control group students. This confirms the result of a previous study suggesting that HOT Lab could improve all aspects of other high order thinking skills (Malik, et al., 2017).

The result of the effect size calculation to measure the effect of HOT Lab implementation in improving students' CTS was 7.84. Referring to the criteria of Cohen et al (2007), it could be interpreted that the effect was large. It can then be concluded that the effect of using HOT Lab on students' CTS was larger than that of the verification lab. This is in line with Wenning's (2011) opinion that cookbook lab is driven step by step instructions requiring minimum intellectual involvement thereby promoting robotic and rule-conforming behaviors.

4 CONCLUSIONS

Generally, we have successfully conducted a study on the implementation of HOT Lab in improving CTS of pre-service physics teachers. The results revealed that the improvement of all CTS aspects of the experimental group who used HOT Lab was significantly different from that of the control group who used verification lab. Fluency was the most improved aspect, and flexibility the least improved in the experimental group. HOT Lab is worth considering to be implemented to teach other physical topics.

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