Effect of Higher Order Thinking Virtual Laboratory (HOTVL) in Electric Circuit on Students’ Creative Thinking Skills

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Abstract. Creative thinking skill is one skill that is very needed in the 21st century. Therefore, development of creative thinking skills through physics teaching and learning is important. This research applies higher order thinking virtual laboratory (HOTVL) on the topic of electric circuit to facilitate students’ creative thinking skills. The research addresses the comparison of the improvement of the creative thinking skills between students who had experiment using HOTVL and verification lab model. This research used a quasi-experiment method with control group pretest-posttest design. The subject of this research are senior high school students in grade XII which were taken using purposive sampling. A sample of seventy (70) students participated in the research. An equivalent number of thirty five (35) students were assigned to the control and experimental group. The result showed that the improvement of the students creative thinking skills who conducting HOTVL model is higher than those who conducting verification lab model. These results indicate that the HOTVL is effective to improve creative thinking skills of the student in the concept of electric circuit.

1. Introduction
Among the skills that one has to possess in order to face the 21st century challenges is the creative thinking skill \([1, 2]\). Developing students’ creative thinking skill has become a priority in this age, as indicated by the advancement of knowledge and technology in various fields \([3]\). Thus, education institutions are demanded to prepare their students to face challenges creatively. The Republic of Indonesia Government has taken concrete steps to prepare Indonesian students facing the 21st century challenges, i.e. by formulating and issuing new curricular policy \([4]\). The 2013 curriculum currently implemented is referring to the 21st century skills \([4]\), which are oriented towards the higher order thinking skills. Physics, as a discipline in science, is a subject taught in Senior High Schools. Physics is a fundamental knowledge developed based on scientific findings pertaining to daily events and occurrences. With such nature, physics learning is oriented towards instilling knowledge of fundamental concepts, developing scientific skills, and improving thinking skills, in line with the way the scientists formulate physics laws and principles. Physics learning is expected to be a mode to train and equip students with creative thinking skill. As reflected in the objectives of physics learning, the teaching of physics subject in Senior High School level aims to train and develop...
students’ creative thinking skill and communication skill so that they may master physics concepts and principles as well as improve their knowledge [5].

Creative thinking skill is a part of higher order thinking skill, which specifically focuses on findind ideas, generating skills, and producing correct solution of a problem. Creative thinking skill is a skill to generate ideas, solutions, concepts, and theories characterized by uniqueness and originality [6]. Creative thinking is also defined as fluency, flexibility, and uniqueness (originality) in thinking [7]. Torrance (1984) defined four characteristic aspects of creative thinking, i.e. originality, elaboration, fluency, and flexibility [8]. Creative thinking skill is not an innate skill of an individual; rather, it is transferred to a person through learning activities.

One of the ways to facilitate creative thinking skill development is laboratory activities, both the real and the virtual practice. Involving students in laboratory-based science learning activities contributes not only towards the construction of conceptual knowledge, but also towards the development of scientific way of thinking [9]. Learning through laboratory activities plays an important role in cognitive (thinking skill), psychomotor (practice performing skill), and affective (cooperation and appreciation for others) development [10]. Science learning, including physics, should be delivered through scientific inquiry to develop students’ thinking skill, working skill, and scientific behaviors, as well as their communication skill, which is an important life-skill [11]. Therefore, laboratory practice has a great potential to train and develop students’ creative thinking skill, since it develops and improves students’ soft skills and hard skills [12].

However, the condition of todays’ laboratory activities is still far from what is expected. Several previous studies show that 1) laboratory practice at schools is not managed effectively; 2) the experiments practiced in those laboratories are too simple and meaningless; 3) in laboratory activities, students are only demanded to report the result of their observation, seldom are they asked to analyze the interrelationship between the observed variables, to test prediction, or to choose possible explanations of the experiment results; 4) the well-structured and verificative activities do not particularly instigate students’ curiosity, so that they do not improve creative thinking skills much [13]. Verification-based laboratory activities model is commonly tedious, not interactive, and not interesting. Consequently, such laboratory activities will not promote students’ higher order thinking [14]. This condition is worrying because we are in the 21st century, while classroom learning practices have not train the skills that students need to handle the 21st century challenges. Such condition should not be allowed to continue. An immediate solution has to be implemented to change classroom learning practices, because learning is one of the most strategic ways to equip students with the necessary skills.

Higher order thinking laboratory is laboratory practice activities that focus on problem solving using higher order thinking skill. The steps in higher order thinking laboratory model is the combination of CPS (Creative Problem Solving) and PSL (Problem Solving Laboratory) models. The steps in HOT Lab consist of five main processes, i.e. 1) understanding the challenges, 2) generating ideas, 3) preparation for lab work, 4) doing lab work, and 5) communicating and evaluating results [15]. Higher order thinking laboratory model is problem solving activities pertaining to daily physics phenomena (real world problem) through laboratory practice. Science, including physics, entails not only the mastery of knowledge, facts, concepts, or principles, but also the process of discovering and implementing the findings in daily life situations [16]. This can be facilitated through the laboratory practice model. However, the limited availability of equipments and time at schools often hinders such practice [17]. The findings of the present study show that in experimentation based on hands-on experiments, students are frequently preoccupied with handling equipment setups and taking measurements, which questions the effectiveness of laboratory activities based on hands-on experiments as the only environment for promoting scientific understanding [18]. Virtual laboratory can be one of the effective solutions for that problem [19]. Virtual laboratory (virtual lab) is a laboratory designed through computer program, representing the real physical laboratory [20]. Virtual lab may take the form of website or application that allows students to perform simulation of experiments [21]. The implementation of higher order thinking virtual laboratory is expected to improve students’ creative thinking skill in direct current topic of electric circuit material.
2. Methods

The present study employs a quasi-experiment method using pretest-posttest control group design [22], implemented on XII (twelve) grade students selected through purposive sampling. The design begins with the pretest, involving 35 students from the experiment group and 35 students from the control group, all of which come from a public school in West Bandung District. The experiment group is given a treatment of higher order thinking virtual laboratory (HOTVL) model, while the control group is given a treatment of verification virtual laboratory model. Syntax of HOTVL using stages of HOT Lab design developed by Adam et al 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[23]. Of the 11 stages in HOT Lab design, in the exploration and measurement stages of this study using virtual lab PHET. Then, the two group is given posttest. The results of pretest and posttest are then analyzed to obtain the N-gain of creative thinking skill improvement. Creative thinking skill test consists of four aspects, i.e. fluency, flexibility, originality, and elaboration [3].

3. Result and Discussion

The improvement of creative thinking skill can be seen by calculating individual N-gain <g>, calculating the average, and interpreting the result into N-gain category. The data required for the calculation of creative thinking skill improvement are the pre-test and post-test results of both the experiment and the control groups.

| Description     | Experiment Group | Control Group |
|-----------------|------------------|---------------|
|                 | Pretest | Posttest  | Pretest | Posttest |
| Maximum Score   | 12      | 31        | 15      | 24       |
| Minimum Score   | 1       | 19        | 3       | 4        |
| Average Score   | 17.06   | 67.54     | 17.46   | 48.73    |
| Standard Deviation | 8.76   | 9.33      | 8.02    | 9.86     |

| N-gain | 0.61 | 0.37 |

Table 1 shows that the scores of creative thinking skills for both groups are equally elevated. Based on the calculation result, the average score of <g> students creative thinking skill in the experimental group is 0.61, including the medium category is higher than the control group of 0.37, including the medium category.

Recapitulation of average n-gain score for each creative thinking skill aspect for both groups is shown in Table 2.

| Creative Thinking Aspect | N-Gain Experiment Group | N-Gain Control Group |
|--------------------------|-------------------------|----------------------|
| Fluency                  | 0.76                    | 0.53                 |
| Flexibility              | 0.60                    | 0.34                 |
| Originality              | 0.50                    | 0.30                 |
| Elaboration              | 0.42                    | 0.22                 |

Data in Table 2 shows that the four aspects of creative thinking skill improve differently. The fluency and flexibility aspects improve the most in the experiment group, compared to originality and elaboration aspects. This means that students are more able to generate more diverse ideas or responses in solving problems. The lowest average score is that of originality, indicating that the students are not able to produce new or unique ideas.
The improvement of creative thinking skill on fluency and flexibility aspects of the experiment class belongs to High category, while that in control group is in Medium category. These findings confirm a previous study that found that higher order thinking laboratory (HOT Lab) model improved students’ creative thinking skill on the aspects of fluency and flexibility better than verification practice model [26].

The fluency aspect has the highest N-gain improvement in both experiment and control groups. The Q&A (questions and answers) stage of HOT Lab design provides better chance for students to think fluently in asking questions that they use as a reference in solving a problem. One may find a fundamental principle of physics and its problems through asking many questions [27]. Fluency aspect in control group tends to not improve much, because the students are given the steps to conduct experiments in verification laboratory (cookbook) [28]. This finding confirms the previous study that cookbook implementation seldom shows students’ understanding on what they have conducted [29].

To find out the significant differences of students’ creative thinking skills improvement for both the experimental class and control class, statistical tests were performed on the acquisition of the N-gain value of creative thinking skills on the experimental class and control class. The result of statistical test about the improvement of students’ creative thinking skill on experimental and control group is presented in Table 3.

| Table 3. Statistical Test Results of Students’ Creative Thinking Skill improvement |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Group                          | Test of Normality | Test of Homogeneity | Independent sample t-Test |
|                                | Sig.   | Interpretation | Sig.   | Interpretation | Sig.   | Interpretation |
| Experiment                     | 0.200  | Data is normally distributed | 0.687  | Data variance is homogeneous | 0.000  | There is an increasing difference between the two group |
| Control                        | 0.200  | Data is normally distributed |          |                  |        |                  |

Significance at p<0.05

Based on the normality test results (Table 3), both group obtained a significance value larger than $\alpha = 0.05$. This indicates that the data of creative thinking skills improvement is normally distributed. After the data is normally distributed then the homogeneity test is done. Results of homogeneity test (table 4.) obtained significance value of 0.687 where the value is larger than significance level ($\alpha = 0.05$). This indicates that the data of creative thinking skills improvement for both the experimental and control group have the equal variances. If the data of creative thinking skills improvement between the experimental and the control group has been normally distributed and has the equal variance then the independent sample t-test is done.

Based on the test result of independent sample t-test obtained significance value of 0.000 indicating that the value is larger than significance level ($\alpha = 0.05$). Thus, at the 95% confidence level, it’s concluded that there was a difference in the students’ creative thinking skills improvement between the practicum group with applying HOTVL and the group that only using the verification lab. Therefore, it’s informed that at the 0.05 significance level, the creative thinking skill has been significantly improved after applying HOTVL compared to the verification lab.

The findings in the present study prove that students’ involvement in laboratory activities using HOTVL affects their creative thinking skill. Even though students’ creative thinking skill do not achieve the ideal level, it still improves through laboratory activities using HOTVL model. Previous research which states that the application of HOT Lab in the activity of laboratory can improve high-order thinking skills (creative thinking, critical thinking) and communication skills [30-33].
4. Conclusion
The implementation of higher order thinking virtual laboratory (HOTVL) model is more effective improves creative thinking skill in electric circuit topic, compared to the implementation of virtual laboratory verification. Therefore, this model should be considered to be implemented in the learning of other physics concepts.

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References
[1] Binkley M, Erstad O, Herman J, Raizen S, Ripley M, Miller-ricci M, and Rumble M 2012 Defining Twenty-First Century Skills (Newyork: Springer)
[2] Trilling B and Fadel C 2009 21st Century Skills Learning For Life In Our Times (San Francisco: Jossey-Bass)
[3] Alzoubi A M, Qudah M F A, Albursan I S Bakhiet S F, and Adel S A 2016 The Effect of Creative Thinking Education in Enhancing Creative Self-Efficacy and Cognitive Motivation Journal of Educational and Developmental Psychology 6 (1) p 117-130
[4] Sapriadil S, Setiawan A, Suhandi A, Malik A, Safitri D, Lisdiani, S A S, and Hermita N 2018 Optimizing students’ scientific communication skills through higher order thinking virtual laboratory (HOTVL) J.Phys.:Conf.Ser. 1013012050
[5] Depdiknas 2006 Pedoman Khusus Pengembangan Silabus dan Penilaian Mata Pelajaran Fisika (Depdiknas: Jakarta)
[6] Fatt J P T 2000 Fostering Creativity In Education Educational Journal 120 (4) p 744-757
[7] Yakar Z and Baykara H 2014 Inquiry-Based Laboratory Practices in a Science Teacher Training Program. Eurasia Journal of Mathematics, Science and Technology Education 10 (2) p 173-183
[8] Piaw C Y 2004 Creative and Critical Thinking Styles (Malaysia: Universiti Putra Malaysia Press)
[9] Taramopoulos A, Psillos D, and Hatzikraniotis E 2012 Teaching Electric Circuits by Guided Inquiry in Virtual and Real Laboratory Environments Research on E-Learning and ICT in Education p 211–224
[10] Pabellon and Mendoza 2008 Sourcebook on Practical Work for Teacher Trainers: High School Physics Vol 1 (Quezon Cit)
[11] Wenning C J 2012 Levels Of Inquiry : Using Inquiry Spectrum Learning Sequences To Teach Science Journal Physics Teacher Education Online 5 (3) p 11–20
[12] Trivedi R and Sharma P M P 2013 A Study of Students’ Attitude towards Physics Practical at Senior Secondary Level International Journal of Scientific and Research Publications 3 (8) p 3–6
[13] Hofstein A V I and Lunetta V N 2003 The Laboratory in Science Education: Foundations for the Twenty-First Century In Departemen of Science Teaching The Weismann Institute of Science Rehovot 76100 Israel
[14] Maria B, Marjan G, An L, Parappilly M B, Siddiqui S, Zadnik M G, and Shapter J 2013 An Inquiry-Based Approach to Laboratory Experiences : Investigating Students’ Ways of Active Learning International Journal of Innovation in Science and Mathematics Education 21 (5) p 42–53
[15] Malik A and Setiawan A 2016 The Development of Higher Order Thinking Laboratory to Improve Transferable Skills of Students Proceedings 2015 International Conference on Innovation in Engineering and Vocational Education (Bandung), Vol 56 (Amsterdam: Atlantis Press) p 36–40
[16] Wibowo F C and Suhandi A 2013 Penerapan Model Science Creative Learning (SCL) Fisika Berbasis Proyek untuk Meningkatkan Hasil Belajar Kognitif dan Keterampilan Berpikir Kreatif. Jurnal Pendidikan IPA Indonesia 2 (1) p 67–75.
[17] Zacharia Z C, Constantinou C P and Sample A 2008 Comparing the influence of physical and virtual manipulatives in the context of the Physics by Inquiry curriculum: The case of undergraduate students’ conceptual understanding of heat and temperature American Journal Physics 76 p 20–22

[18] Psillos D and Niedderer H 2002 Issues and Questions Regarding the Effectiveness of Labwork Teaching and Learning in the Laboratory p 21–22

[19] Zacharia Z C and Olympiou G 2011 Physical versus virtual manipulative experimentation in physics learning. Learning and Instruction 21 (3) p 317–331

[20] Babateen H 2011 The role of Virtual Laboratories in Science Education 2011 5th International Conference on Distance Learning and Education(Singapore) Vol 12 (Singapore: IACSIT Press) p 100–104

[21] Bajpai M and Kumar A 2015 Effect of Virtual Laboratory on Students’ Conceptual Achievement in Physics International Journal of Current Research 7 (2) p 12808-12813

[22] Fraenkel J R, Wallen N E and Hyun H H 2012 How To Design and Evaluate Research in Education (8th ed.) (New York: McGraw-Hill)

[23] Malik A, Setiawan A, Suhandi, and Permanasari A 2017 Hot lab-based practicum guide for pre-service physics IOP Conf. Ser.: Mater. Sci.Eng. 288012027

[24] Alrubaie F, Gnanamalar E and Daniel S 2014 Developing a Creative Thinking Test for Iraqi Physics Students. International Journal of Mathematics and Physical Sciences Research 2 (1) p 80–84

[25] Torrance E P 1990 Torrance tests of creative thinking verbal forms A and B: Manual for scoring and interpreting results Benseville: IL: Scholastic Testing Service, Inc

[26] Malik A, Setiawan A, Suhandi A, and Permanasari A 2017 Enhancing pre-service physics teachers’ creative thinking skills through HOT Lab design. AIP Conf. Proc. 1868 p 070001-1–070001-7

[27] Sternberg R J 2012 The Assessment of Creativity: An Investment-Based Approach Creativity Research Journal 24 (1) p 3–12

[28] Grooms J, Sampson V and Golden, B 2014 International Journal of Science Comparing the Effectiveness of Verification and Inquiry Laboratories in Supporting Undergraduate Science Students in Constructing Arguments Around Socioscientific Issues International Journal of Science Education 36 (9) p 1412–1433

[29] Aufschnaiter C von and Aufschnaiter S von 2007 University Students’ Activities, Thinking and Learning During Laboratory Work European Journal of Physics 28 (3) p 51-60

[30] Setiawan A, Malik A, Suhandi, and Permanasari A 2018 Effect of higher order thinking laboratory on the improvement of critical dan creative thinking skills IOP Conf.Ser.: Mater. Sci.Eng. 306012008

[31] Malik A, Setiawan A, Suhandi, and Permanasari A 2017 Learning experience on transformer using hot lab for pre-service physics teacher’s J.Phys.:Conf. Ser. 895012140

[32] Malik A, Setiawan A, Suhandi, and Permanasari A, Dirgantara Y, Yuniarti H, Sapriadil S, and Hermita N 2017 Enhancing communication skills of pre-service physics teacher through hot lab related to electric circuit J.Phys.:Conf. Ser. 953012017

[33] Malik A, Setiawan A, Suhandi, and Permanasari A, Samsudin A, Safitri D, Lisdiani S A S, Sapriadil S and Hermita N 2018 Using hot lab to increase pre-service physics teacher’s critical thinking skills related to the topic of RLC circuit J.Phys.:Conf. Ser. 1013012023