Using Inquiry-based Laboratory Activities in Lights and Optics Topic to Improve Students’ Conceptual Understanding

T B Wardani1*, A Widodo2 and N Winarno1

1International Program on Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
2Department of Biology Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

*tiara.budi.wardani@student.upi.edu

Abstract. The aim of this research is to investigate the effect of inquiry based laboratory activity by comparing the inquiry and non-inquiry laboratory activity in terms of students’ conceptual understanding among junior high school students in the topic of lights and optics. It also investigated the effectiveness of this method to male and female students. The method used in this research was quasi experiment which used two classes, where one class was randomly taken as the experimental class and the other one as the control class. Each class consists of 20 students. The result of this research shows that the average gain of the experimental class was 0.70, while the control one got 0.56. Means that the conceptual understanding of experimental class is statistically different with the control one. It is concluded that the inquiry based laboratory activity give better effect in improving students’ conceptual understanding and inquiry-based laboratory activities were found to have the same effectiveness for male and female students.

1. Introduction

Indonesia National Curriculum of 2013 states that teaching learning process at school should guide the students to experience five learning aspects which are being emphasized in this curriculum, they are observing, questioning, experimenting, associating, and communicating [1]. Those five learning experiences are used by the government to support Indonesia in reaching the education objectives. The mission and orientation of Indonesia National Curriculum of 2013 is translated in educational practice with the specific purpose so that learners have the necessary competences to the lives of society today and in the future. The competences are included: (1) foster religious attitude and high social ethics in the life of society, nation and state; (2) the acquisition of knowledge; (3) have the skills or the ability to apply knowledge in order to conduct scientific inquiry, problem solving, and the making of creative works related to everyday life [2].

But unfortunately, government’s expectations have not been reached yet. Because in reality, the students’ acquisition of knowledge and ability to apply knowledge is still low. It can be seen from international comparative survey such as PISA (Programme for International Student Assessment), the score of Indonesia in science is only 403, while the average score is 497 [3]. The poor performance of students attests to the fact that the teaching and learning have not been effective enough [4]. It depicts lack of acquisition of the required skills which may be as a result of inadequate exposure of learners to an inquiry laboratory activities. It is an indication of a gap in the system of teaching and learning of science in Junior High School which require investigation and remediation [4].
The low score Indonesian students in science is also occured because natural science subject is considered as one of the subjects that has special difficulties for many students included for Junior High School students as teenagers [5]. These difficulties then could lead students to have low motivation in learning science, although actually in this school level they should have a good concept understanding about natural science in order to be their foundation for learning natural science in the next school level. It is in line with what stated by Anderman and Sinatra that the state of science education for teenagers is at an important crossroad [6].

As one of the main part of science subject, light and optics topic is also hard to be learned by the students. Light and optics is a rapidly developing and often encountered its technological practices in everyday lives [7]. However teaching and learning the subject of lights and optics is challenging for teachers and students [7]. Teaching the teenagers or adolescents will also emerge unique challenges for science educators. It is because in the adolescent phase students are facing the transition phase means that students are in the process of trying to understand the abstract concepts where in the previous school level or child phase they only learn the concrete one [6].

To solve those problems, educators should provide a form of teaching and learning activity which can attract the interest of students [7]. Teacher could facilitate students with learning activity which engage students to think deeply about the learning material in appropriate level. The conceptual mastery of the students can be enhanced when the students were provided with “learn-by-doing” or kinesthetic modes of knowledge acquisition [4]. Learning science including physics is not only the acquisition in the form of facts, concept, principles or theory but learning will be more meaningful if the students experience or observe it directly [7].

A focus on meaningful learning is consistent with the view of learning as knowledge construction, in which students seek to make sense of their experiences [8]. Science is better to be taught using experimentation, it should be taught through activity-based approach in a well-equipped laboratory learning environment [9]. Inquiry-based learning is one approach using more student-directed, interactive methods of learning and focusing on learning how to learn [10]. The laboratory can help the teachers to demonstrate practically some of the principles taught in theory. But however, based on a survey done by the researcher in 2016, it showed that in Indonesia there is still lack inquiry laboratory activity conducted to support the learning process. So, inquiry based laboratory activity is expected to have positive effects toward Junior High School students’ conceptual mastery.

Previously, there are several researches already conducted to test the effectiveness of inquiry based laboratory method, such as a research conducted by Azer et al. (2013), this research investigating the students’ conceptual mastery and attitude after treated with laboratory learning [4]. Also a research conducted by Bünning (2013) which evaluate empirically the effects of experimental learning on learning achievement [11]. And, the research conducted by Olubu (2015) also investigate the effects of laboratory learning environment on students’ learning outcomes in secondary school Chemistry. Such research could further suggest changes to educational standards and practices [4]. If inquiry-based learning can improve student outcomes in physical science, then similar strategies could work in other subject areas and for other age groups. This research was initiated to evaluate the effectiveness of using inquiry-based laboratory activities among 8th Grade students in terms of students’ conceptual mastery (based on the Revision of Bloom’s Taxonomy by Anderson and Krathwohl [12]) in lights and optics topic. As well, this research also examined the differential effectiveness of inquiry activities for male and female students.

2. Experimental Method
The research method used in this research is Quasi Experiment. Quasi experiment includes assignment, but not random assignment of participants to groups [13]. This is because the researcher cannot artificially create groups for the experiment. This method is appropriate with the purpose of the research which is investigating the effect of inquiry laboratory activity by comparing the inquiry and non-inquiry laboratory activity in terms of students’ conceptual understanding among junior high school students in the topic of lights and optics. The design that will be used in this research is pre-test and post-test design. The researcher assigns intact groups of the experimental and control groups,
administers a pre-test to both groups, conducts experimental treatment activities with the experimental group only, and then administers a post-test to assess the differences between the two groups [13].

| Table 1. Pre-test and post-test design |
|-----------------------------------------|
| Select Control Class | Pre-test | Non-inquiry based laboratory activity | Post-test |
| Select Experimental Class | Pre-test | Inquiry based laboratory activity | Post-test |

This research conducted in one of Junior High School in Kabupaten Bandung which implements the Indonesia National Curriculum of 2013. The participants of this research is 44 students from 8th grade. The samples are two classes in eighth grade, one of the classes will act as a control group, while the other one will be as experimental group. There are 22 students in each group, the experimental group consist of 10 females and 12 males while the control group consist of 13 females and 9 males. Their ages ranged between 14 to 16 years old.

The sampling technique was Cluster Random Sampling. It is randomly selecting only one cluster as a sample and then observing all individuals within that cluster[14]. Even if there are a large number of individuals within the cluster, it is the cluster that has been randomly selected, rather than individuals.

3. Result and Discussion

3.1. Conceptual understanding

To explore the relative effectiveness of the two modes of instruction in the research, firstly the gained score was calculated by subtracting the post test with the pretest score and divided by 100. Then the average mean of the gain (the mean divided by the number of students in a class) was determined for each class. Using the class as the unit of analysis, effect sizes were calculated statistically to describe the magnitude of the difference mean between inquiry and non-inquiry class. But before it, the normality and homogeneity of the data were checked as the consideration to choose the appropriate statistic method. The normality and homogeneity results are shown in the Table 2 and Table 3.

| Table 2. The result of normality test |
|--------------------------------------|
| Methods | Kolmogorov-Smirnov | Shapiro-Wilk |
|         | Statistic | df | Sig. | Statistic | df | Sig. |
| 1       | .188     | 20 | .063 | .910      | 20 | .063 |
| 2       | .151     | 20 | .200* | .951      | 20 | .376 |

a. Lilliefors Significance Correction

| Table 3. The result of homogeneity of variance test |
|----------------------------------------------------|
| Methods                                    | Levene Statistic | df1 | df2 | Sig. |
| Based on Mean                             | .138             | 1   | 38  | .713 |
| Based on Median                           | .140             | 1   | 38  | .710 |
| Based on Median and with adjusted df      | .140             | 1   | 37.291 | .710 |
| Based on trimmed mean                     | .124             | 1   | 38  | .726 |
In the result of normality test (Table 2.) there are two types of calculation which are Kolmogorov-Smirnov and Saphiro-Wilk. The first type is used if there are a lot of data (>50), while the second one used for the small size data. In this research, the data are less of 50, so it shows a normality significant number of 0.063 for experimental class and 0.376 for the control class. This number can be interpreted that the data is normally distributed because Sig>0.05 (for educational field). For the homogenity test (Table 3.) it shows a significant number of 0.713 which is also bigger than 0.05. Both tables above denoted that the data gained by the researcher is normal and homogen.

| Table 4. Independent samples test |
|----------------------------------|
| t-test for Equality of Means      |
|                                  |
|                                | t  | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed          | 3.477 | 38 | .001           | .13500          | .03883               |
| Equal variances not assumed      | 3.477 | 37.953 | .001 | .13500 | .03883 |

The normal and homogen data is appropriate to be processed using t-test, the result of t-test is showed as above. It involved the analysis of variance with the conceptual understanding (gained score) as the dependent variable and the method of instruction (inquiry versus non-inquiry) as the independent variable. In the term of conceptual understanding, students in inquiry classes perceived a statistically significant bigger gain than did students in the non-inquiry classes. Students in the inquiry class scored slightly better than did students in the non-inquiry group.

During the learning process, researcher noted that students initially struggled more in the inquiry classes to design the experiments. But, as the treatment period progressed, students became more and more familiar with the overall process and required less prompting from the teachers. They also seen to be more ingenious to run the science tools. Overall, students in the inquiry class appear to have benefited somewhat from the instructional method.

It is in line with the result of previous researches that also investigated the inquiry based laboratory activity, such as the result of a research conducted by Wolf and Fraser (2007) which showed that inquiry based laboratory activity was effective to improve students’ achievement [10], research conducted by Wang (2008) also showed the same result, it showed inquiry based laboratory activity gave a statistically significant effect toward the students’ conceptual changes across levels of prior knowledge and reading ability [15].

3.2. Differential effectiveness of instructional methods for different genders

Where as the analyses reported in the previous section explored differences between the two instructional groups for the whole sample, the purpose of the analyses reported in this section was to investigate whether the two methods of instruction (inquiry and non-inquiry) were differentially effective for males and females. This involved examining the interactions between instructional method and gender for conceptual understanding with the sample of 44 students in 2 classes.
At a glance, the graphic above can be interpreted that the female students gained bigger score in inquiry class, while the male score of both classes are not really different. But observing the data using graphic was not enough. It needed to be processed using statistical tools. It employed a two-way ANOVA for which the two independent variables were method of instruction and students’ gender. The univariate ANOVA was interpreted for each scale (see Table 5). The result of this statistical analysis shows that the Sig. of methods*gender is 0.420, it means that the inquiry based laboratory activities give the same effect to both gender (Sig>0.05). Therefore, it denoted that the inquiry based laboratory activity give the same effect either to male or female students.

Table 5. Tests of between-subjects effects
Dependent variable: conceptual understanding

| Source                      | df | Mean Square | F      | Sig. |
|-----------------------------|----|-------------|--------|------|
| Corrected Model             | 3  | .077        | 5.305  | .004 |
| Intercept                   | 1  | 15.588      | 1071.723 | .000 |
| Methods                     | 1  | .199        | 13.686 | .001 |
| Gender                      | 1  | .039        | 2.677  | .110 |
| Methods * Gender            | 1  | .010        | .667   | .420 |
| Total                       | 40 |             |        |      |
| Corrected Total             | 39 |             |        |      |

a. R Squared = .307 (Adjusted R Squared = .249)

4. Conclusion
The average gain of the experimental class was 0.70, while the control one got 0.56. Based on the data analysis, it can be concluded that the inquiry based laboratory activities appears to have more benefited the students in terms of conceptual understanding. The students in the inquiry class scored slightly better than did students in the non-inquiry group, they perceived a statistically significantly bigger gain than did students in the non-inquiry classes. The gender difference did not gave any significant different toward the effectiveness of the method. The method seen to have the same effect to both either male or female students.

Acknowledgments
Author’s wishing to acknowledge the principal of the school for the permission to conduct the research (teaching in the class for several meetings).
References

[1] Brookes Publishing. (2012, February). *5 tips for getting all your students engaged in learning*. Retrieved October 18, 2016, from: http://archive.brookespublishing.com/articles/ed-article-0212.htm.

[2] Kementerian Pendidikan dan Kebudayaan. (2015). *Kurikulum 2013 Kompetensi Dasar*. Jakarta: Kemdikbud.

[3] OECD Data. (2015). *Science Performance PISA*. Retrieved December 12, 2016, from OECD Data: https://data.oecd.org/pisa/science-performance-pisa.htm.

[4] Olubu, Odutuyi Musili (2015). Effects of Laboratory Learning Environment on Students’ Learning Outcomes in Secondary School Chemistry. *International Journal of Arts & Sciences*, 8 (2), pg. 507-525.

[5] BBC News. (2005, June 19). *Science dull and hard, pupils say*. Retrieved October 17, 2016, from BBC News: http://news.bbc.co.uk/2/hi/uk_news/education/4100936.stm.

[6] Anderson & Sinatra. (2008). *The Challenges of Teaching and Learning about Science in the 21st Century: Exploring*. Las Vegas: National Academy of Education.

[7] Tural, G. (2015). Cross-Grade Comparison of Students’ Conceptual Understanding with Lenses in Geometric Optics. *Science Education International Journal*, 26 (3), pg. 325-346.

[8] Ausubel, David P. (1969). *School learning: an introduction to education psychology*. New York: Holt, Rinehart and Winston, Inc.

[9] Azer, S.A., Hasamoto,R., Al-Nassar,S., Somily, A.,& AlSaadi, MuslimM. (2013). Introducing integrated laboratory classes in a PBL curriculum: impact on student’s learning and satisfaction. *BMC Medical Education*, 13 (71), pg. 1-12.

[10] Wolf, S.J.,& Fraser, B.J. (2007). Learning Environment, Attitudes and Achievement among Middle-school Science Students Using Inquiry-based Laboratory Activities. *Springer Science + Business Media B.V.*, 38, pg. 321–341.

[11] Bunning, Frank. (2013). Effects of experimental learning outcomes of an empirical study in the vocational field of structural engineering. *International Journal of Training Research*, 11 (1), pg. 44-55.

[12] Anderson, L.W.,& Krathwohl, D.R. (2001). *A Taxonomy for Learning, Teaching and Assessing (A Revision of Bloom's Taxonomy of Educational Objectives)*. United States: Addison Wesley Longman, Inc.

[13] Cresswel, John W. (2012). *Educational research: planning, conducting, and evaluating quantitative and qualitative research*. United States of America. Pearson.

[14] Fraenkel, J. R., Wallen, Norman E., & Hyun Helen H. (2007). *How to Design and Evaluate Research in Education*. New York: McGraw-Hill, Inc.

[15] Wang, Jing-Ru., Wang, Yuh-Chao., Tai, Hsin-Jung. & Chen, Wen-Ju. (2010). Investigating The Effectiveness of Inquiry-Based Instruction on Students With Different Prior Knowledge and Reading Abilities. *International Journal of Science and Mathematics Education*, 8, pg. 801-820