Jurnal Pengajaran MIPA
Vol. 22, No. 2, October 2017, XXX.
ISSN 1412-0917 (print)/ 2443-3616 (online)

DOI: 10.18269/jpmipa.v22i2.XXX

JPMIPA
Jurnal Pengajaran Matematika Dan Ilmu Pengetahuan Alam

IMPROVING STUDENTS' SCIENTIFIC LITERACY ON ENVIRONMENTAL POLLUTION TOPICS THROUGH LABORATORY-BASED DISCOVERY LEARNING

Bibin Rubini, Indarini Dwi Pursitasari, Didit Ardianto, and Haris Nugraha

Departement of Science Education, Universitas Pakuan
Jl. Pakuan PO BOX 452, Ciheuleut, Bogor, West Java, Indonesia
Email: bibinrubini@unpak.ac.id

ABSTRACT

The purpose of science education is to develop scientific literacy. This study investigated the effectiveness of Laboratory-Based Discovery Learning (LBDL) in improving students' scientific literacy. Samples were 70 seventh grade students in Bogor, West Java. Students were divided into two experimental groups, LBDL and Non Laboratory-Based Discovery Learning (NLBDL) group, 35 students in each experimental group. Research instrument was scientific literacy test with 30 multiple choice questions about environmental pollution. Results suggested that both types of discovery learning increase students' scientific literacy, in which LBDL proved to create a better improvement in terms of content and science process domain. Content and science process domain improvement for every indicator were also discussed. Laboratory-Based Discovery Learning effectively improved students' scientific literacy because it provides students with the opportunity to engage in hands-on activities which foster learning and meaningful discussion which facilitate knowledge transfer.

Keywords: discovery-based learning; laboratory works; scientific literacy; science education

How to cite: Rubini, B., Pursitasari, I.D., Ardianto, D., & Nugraha, H. (2017). Improving Scientific Literacy on Environmental Topics through Laboratory-Based Discovery Learning, *Jurnal Pengajaran MIPA*, 22(2), XXX.

INTRODUCTION

The purpose of science education is to enhance students' scientific literacy (see Holbrook, 2010) and develop essential competencies to become socially responsive citizens (Roth and Lee, 2004). Lawson (2010) stated that science instructions should design and teach lessons that will help the students to understand how science works, to become scientifically literate students. Scientific literacy can be interpreted as the ability to creatively utilize relevant evidence-based scientific knowledge and skills in solving scientific problems, as well as making responsible decisions in daily and professional life (Holbrook and Rannikmae, 2009). Scientifically literate students are expected to have critical thinking skills and to evaluate their knowledge to solve problem and making decision (see Soobard and Rannikmae, 2011) because critical thinking is a vital competence for responding to social issues and contributing to the community (ten Dam and Volman, 2004). Research results indicated that students still faces difficulties in responding to socio-scientific issues (Sadler, 2009; Jho, Yoon, and Kim, 2014; Dawson and Carson, 2016). Studies also revealed that students have difficulty in using their knowledge for making decision on social issues (Jho et al., 2014), in evaluating relevant evidence and making an informed decisions on socio-scientific issues (Sadler, 2009). Similarly, (Dawson and Carson, 2016) found that students' reasoning skills in making decision on socio-scientific issues are still only at level 2 and 3, which are categorized as low.

Human effect on the environment such as environmental pollution is one of pressing socio-scientific issues that the students' have to understand because scientific knowledge and wisdom are needed to make an informed decision about how to minimize human activity adverse effect to the environment and creating a more sustainable biosphere (Lubchenco, 1998). Important components of scientific literacy are the understanding of how to use natural resources and to manage environmental quality in which 2006 PISA results indicated that students awareness of environmental issues is connected with a greater sense of responsibility for sustainable development (Bybee, 2008). In terms of students in Indonesia, PISA's (OECD, 2014 ; 2016) and research results (Ariyanti, Ramli, and Prayitno, 2016; Rachmatullah, Diana, and Rustaman, 2016; Rusilowati, Kurniawati, Nugroho, and

Widiyatmoko, 2016) indicated students' poor scientific literacy. Both 2012 and 2014 PISA's results showed that Indonesian students' scientific literacy was still below OECD's average (OECD, 2014; 2016). Ariyanti et al. (2016) evaluated Indonesian students' scientific literacy using Nature of Science Literacy Test (NOSLiT), Rachmatullah et al. (2016) used Scientific Literacy Assessment (SLA), while Rusilowati et al. (2016) used Scientific Literacy Evaluation Instruments, and although evaluation tools were differed, the results also indicated that Indonesian students' scientific literacy were low.

Guided discovery-based learning is one of learning approaches suited for improving students' scientific literacy (Alfieri, Brooks, Aldrich, and Tenenbaum, 2011; Nbina, 2013;Ardianto and Rubini, 2016) and science laboratory is a learning environment where students can develop their understanding about scientific concept (Hofstein and Lunetta, 2004). In terms of scientific literacy, National Research Council (NRC, 1996) emphasize laboratory works as an important element in achieving scientific literacy. Therefore, this study investigated how laboratory-based discovery learning improves students' scientific literacy on environmental pollution topics.

METHODS

This quasi-experiment with non-randomized static group pretest-posttest design study was conducted in one of junior high school in Bogor, West Java, Indonesia. A total of 70 seventh grade students were involved in this study, in which they were divided into two experimental groups, 35 students in each experimental group I and II. The experimental group I was given laboratory-based discovery learning (LBDL group) while experimental group II was given non laboratory-based discovery learning (NLBDL group). In LBDL group, knowldege acquisition was facilitated by laboratory works while in NLBDL knowledge were obtained from scientific articles and videos. Learning activities in each group are presented in Table 1.

Students' scientific literacy (content and also science process domain) was evaluated with thirty (30) multiple choice questions adopted from 2012's OECD *Programme for International Student Assessment* (PISA) questions. Questions were deemed valid (0.50 or sufficient) and reliable (0.96 or high). The science content evaluated were air, water, and soil pollution whereas science process evaluated were identifying scientific issues, explaining scientific phenomena, and utilizing scientific evidence. Question example is presented in Figure 1. Improvement in students' scientific literacy was measured by N-Gain score and difference between treatments was measured statistically. N-Gain scores were categorized according to Hake (1998).

Table 1. Learning Activities in Laboratory-Based and Non Laboratory-Based Discovery Learning

Topics	Laboratory-Based Discovery Learning (LBDL)	Non Laboratory-Based Discovery Learning (NBDL)
Water Pollution	Students work in groups to conduct laboratory activity and to identify polluted water according to its physicochemical properties. Students also conduct laboratory works about the effect of water pollution to organisms.	Students work in groups and asked to identify polluted water according to its physicochemical properties and its effect to the environment from scientific articles (provided by the teacher).
Air Pollution	Students work in group to search information about the source of air pollution from scientific articles and to subsequently conduct laboratory activity to identify the effect of acid rain to the organisms.	Students search information about air pollution and the effect of acid rain from video (clips) provided by the teacher.
Soil Pollution	Students work in group to search information about the source of soil pollution from scientific articles and to subsequently conduct laboratory activity to identify polluted and unpolluted soil according to its physicochemical properties.	Students work in group to identify polluted and unpolluted soil according to its physicochemical properties and its effect to the environment from scientific articles (provided by the teacher).

Drinking Water

70% of human body comprises of water. Water is important to human because water act as a solvent and plays pivotal role in transporting beneficial ions from what we consumed everyday. Water suitability as drinking water is based on its compliance to physicochemical and biological standard. Table 1.1 depicts water testing results from four water samples.

Table 1.1 Physicochemical Properties of Water Sampels from Bogor, West Java

Parameter	Standard	Water Sample No.			
		1	2	3	4
Odor	-	Odorless	Odorless	Odorless	Odorless
Turbidity	-	Clear	Clear	Clear	Murky
Taste	-	Tasteless	Tasteless	Tasteless	Flavorless
Color	-	Clear	Yellowish	Clear	Blackish
pH	-	6,8	6,7	7	7,2
E Coli	1/100 mL	0/100 mL	5/100 mL	3/100 mL	4/100 mL

According to data in Table 1, which water sample can be considered as suitable drinking water?
a. sample 1
b. sample 2
c. sample 3
d. sample 4

Figure 1. One of Question Example for Water Pollution Topic

RESULTS AND DISCUSSION

Average pretest score for Laboratory- Based Discovery Learning (LBDL) and Non Laboratory- Based Discovery Learning (NLBDL) was 37.43 and 34.43, respectively. Pretest scores between LBDL and NLBDL students indicates similar prior ability (F_{value}=1.03 < F_{table}=1.77). Both groups achieved better posttest scores average in which LBDL achieved 71.00 while NLBDL achieved 55.86. Improvement in both discovery learning groups is in line with Balim (2009) finding that discovery learning improves students' achievement and inquiry skills because in discovery learning, students actively involved in the process of knowledge acquisition. This is also in similar vein with others studies (Alfieri, et al.,2011; Nbina, 2013; Ardianto and Rubini, 2016).

Improvement for LBDL students was considered as high (N-Gain 52%) whereas improvement for NLBDL students was considered as moderate (N-Gain 31%). LBDL group achieve higher test scores than NLBDL group in which scientific literacy difference between groups was statistically significant (t_{value} = 19.045 > t_{table} =1.995, p-value = 0.00). These indicates that LBDL was more effective in improving scientific literacy than NLBDL. In terms of environmental content (Figure 2), LBDL students achieve highest improvement in soil pollution (*N-Gain* 75.3%) and lowest in air pollution (*N-Gain* 47.2%) content. On the other hand, reverse results were found in NLBDL students in which the highest improvement was found in air pollution (*N-Gain* 37.9%) while the lowest was found in soil pollution (*N-Gain* 22.09%) content. In overall, LBDL students achieve higher content literacy (*N-Gain* 57.84%) than NLBDL students (*N-Gain* 29.31%). In terms of science process ability, LBDL students also outperformed NLBDL students in all three science process indicators (Table 2).

There are two keys factors in Laboratory-Based Discovery Learning (LBDL) ability to improve scientific literacy: hands-on activity which fosters learning and discussion process. In LBDL, laboratory activities enable the students to actively search, evaluate, and acquire scientific concept in which Gillies and Nichols (2015) stated that students' active involvement in scientific activities such as laboratory works or experiments will enable them to identify solution, explain phenomenon, elaborate results, and evaluate findings. In contrast, knowledge acquisition in Non Laboratory-Based Discovery Learning (NLBDL) only happens by reading scientific articles or watching videos without actually doing experiment. Ritchie, Tomas, and Tones (2011) stated that scientific writing is an inseparable part of scientific literacy and making scientific writing can enhanced students' scientific literacy. In NLBDL, scientific writing is indeed a part of the learning approach but without the process of *making* the scientific writing. This suggested that

Table 2. Science Process Indicators Score for Laboratory- Based Discovery Learning (LBDL) and Non Laboratory- Based Discovery Learning (NLBDL)

Science Process Indicators	**Pretest**		**Posttest**		***N-Gain%***	
	LBDL	NLBDL	LBDL	NLBDL	LBDL	NLBDL
Identifying scientific Issues	37,86	30,71	73,21	57,86	56.89	39.18
Explaining scientific phenomenon	39,68	38,10	74,60	53,33	57.89	24.60
Utilizing scientific evidence	38,19	37,38	62,86	55,24	39.91	28.52

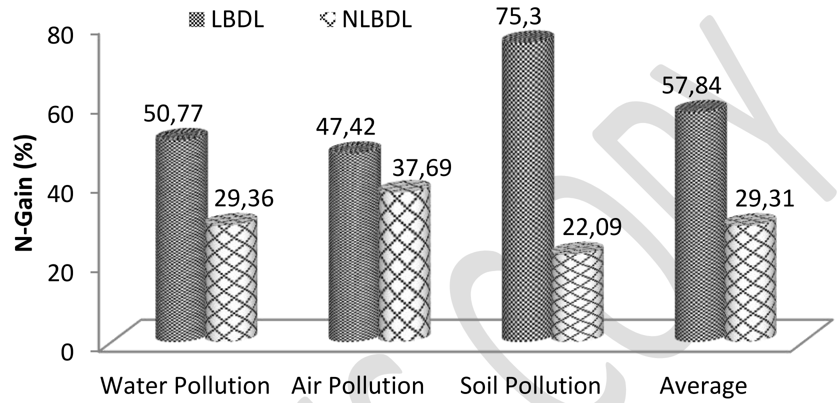

Figure 2. Improvement in Each Environmental Content

hands-on experience makes all the difference. The sentiment is also in line with NRC (1996) as well as others (Hofstein and Lunetta, 2004; Hofstein and Mamlok-Naaman (2007) which stated the importance of science laboratory activities in developing scientific literacy. Widodo, Maria, and Fitriani (2016) study further emphasize the importance of laboratory activity in science education in which they even found that either laboratory activity (real or virtual laboratory) can facilitate science learning.

Another key determinant in LBDL success in improving students' scientific literacy was discussion process. Kuhn and Udell (2003) stated that discussion can improve students' conceptual understanding and in terms of LBDL, interaction with other students before, within, and after laboratory activity creates learning environment in which knowledge transfer happen seamlessly. Continuous discussion opportunity allows the students to always have the occasion to share their ideas as well as giving and receiving feedback from one another so that imperfect conceptual understanding can be detected and fixed immediately. Swakk, Jong and Jolingen (2004) stated that learning with empirical cycle (process approach) such as collecting and classifying information, composing hypothetical assumption, making prediction, interpreting experiment results, and also drawing conclusion, can improve students' inquiry skills and cognitive process because this cyclical process give the students the opportunity to think analytically. Students in NLBDL also only involve in discussion activity when they were engaged in Q&A session with their teacher so that meaningful interaction and discussion were limited. Abundant opportunity to do inquiry processes and activities makes Laboratory-Based Discovery Learning more effective in improving students' scientific literacy on environmental topics than Non Laboratory-Based Discovery Learning.

CONCLUSION

Laboratory-Based Discovery Learning effectively improved students' literacy because it provides students with the opportunity to engage in hands-on activities which foster learning and meaningful discussion which facilitate knowledge transfer.

Laboratory activities in this study were limited to real laboratory activities. Therefore, research exploring virtual laboratory effectiveness in improving students' scientific literacy can be put into consideration for further research in science education.

REFERENCES

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does Discovery-Based Instruction Enhance Learning? *Journal of Educational Psychology*, *103*(1), 1–18.

Ardianto, D., & Rubini, B. (2016). Comparison of students' scientific literacy in integrated science learning through model of guided discovery and problem based learning. *Jurnal Pendidikan IPA Indonesia*, *5*(1), 31–37.

Ariyanti, A. I. P., Ramli, M., & Prayitno, B. A. (2016). Preliminary Study on Developing Science Literacy Test for High School Students in Indonesia. *Proceeding of International Conference on Teacher Training and Education*, *1*(1), 284–289.

Balim, A. G. (2009). The Effects of Discovery Learning on Students ' Success and Inquiry Learning Skills. *Eurasian Journal of Educational Research*, *35*(35), 1–20.

Bybee, R. W. (2008). Scientific literacy, environmental issues, and PISA 2006: The 2008 Paul F-Brandwein lecture. *Journal of Science Education and Technology*, *17*(6), 566–585.

Dawson, V., & Carson, K. (2016). Using climate change scenarios to assess high school students' argumentation skills. *Research in Science & Technological Education*, *5143*(September), 1–16.

Gillies, R. M., & Nichols, K. (2015). How to Support Primary Teachers' Implementation of Inquiry: Teachers' Reflections on Teaching Cooperative Inquiry-Based Science. *Research in Science Education*, *45*(2), 171–191.

Hake, R.R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses, *American Journal of Physics*, 66(1), 64-74.

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education*, *88*(1), 28–54.

Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: the state of the art. *Chemistry Education Research and Practice*, *8*(2), 105.

Holbrook, J. (2010). Education through science as a motivational innovation for science education for all. *Science Education International*, *21*(2), 80–91.

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education*, *4*(3), 275–288.

Nbina, J.B. (2013). The Relative Effectiveness of Guided Discovery and Demonstration Teaching Methods on Achievement of Chemistry Students of Different levels of Scientific Literacy. *Journal of Research in Education and Society*, *4*(1), 1–8.

National Research Council. (1996). *National Science Education Standards*.Washington, D.C.: National Academy Press.

Jho, H., Yoon, H.G., & Kim, M. (2014). The Relationship of Science Knowledge, Attitude and Decision Making on Socio-scientific Issues: The Case Study of Students' Debates on a Nuclear Power Plant in Korea. *Science & Education*, *23*(5), 1131–1151.

Kuhn, D., & Udell, W. (2011). The Development of Argument Skills. *Child Development*, *74*(5), 1245–1260.

Lawson, A. E. (2010). Basic inferences of scientific reasoning, argumentation, and discovery. *Science Education*, *94*(2), 336–364.

Lubchenco, J. (1998). Entering the century of the environment: A new social contract for science. *Science*, *279*(5350), 491-497.

Rachmatullah, A., Diana, S., & Rustaman, N. Y. (2016). Profile of middle school students on scientific literacy achievements by using scientific literacy assessments (SLA). *AIP Conference Proceedings*, *1708*(2016), 080008 1-5.

Ritchie, S. M., Tomas, L., & Tones, M. (2011). Writing stories to enhance scientific literacy. *International Journal of Science Education*, *33*(5), 685–707.

Roth, W. M., & Lee, S. (2004). Science Education as/for Participation in the Community. *Science Education*, *88*(2), 263–291.

Rusilowati, A., Kurniawati, L., Nugroho, S. E., & Widiyatmoko, A. (2016). Developing an instrument of scientific literacy asessment on the cycle theme. *International Journal of Environmental and Science Education*, *11*(12), 5718–5727.

Sadler, T. D. (2009). Socioscientific issues in science education: Labels, reasoning, and transfer. *Cultural Studies of Science Education*, *4*(3), 697–703.

Soobard, R., & Rannikmäe, M. (2011). Assessing Student's Level of Scientific Literacy Using Interdisciplinary Scenarios. *Science Education International*, *22*(2), 133–144.

Swaak, J., De Jong, T., & Van Joolingen, W. R. (2004). The effects of discovery learning and expository instruction on the acquisition of definitional and intuitive knowledge. *Journal of Computer Assisted Learning*, *20*(4), 225–234.

ten Dam, G., & Volman, M. (2004). Critical thinking as a citizenship competence: Teaching strategies. *Learning and Instruction*, *14*(4), 359–379.

OECD. (2014). *PISA 2012 Results: What Students Know and Can Do (Student Performance in Mathematics, Reading and Sciences)*. Paris: OECD Publicatiotins.

OECD. (2016). *PISA 2015 results in focus*. Paris: OECD Publications.

Widodo, A., Maria, R.A., & Fitriani, A. (2016). Peranan Praktikum Riil Dan Praktikum Virtual Dalam Membangun Kreatifitas Siswa. *Jurnal Pengajaran MIPA*, *21* (1) 92-102.