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Improving Student's Scientific Abilities by Using Guided Inquiry Laboratory

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ABSTRACT

This article describes a study of student activities in Earth and Space Science (IPBA) laboratory, which were designed to help physics teacher candidate for improving scientific abilities that are valuable in the work place. In these labs students design and conduct their own experiments. This study, we started to study whether the IPBA laboratory can support students not only write like scientists but also engage in do like scientists while doing the laboratory. For example, to represent physical processes in multiple ways; to modify a qualitative explanation; to design an experimental investigation; to collect and analyze data; to evaluate experimental predictions and outcomes, conceptual claims, problem solutions, and models, and to communicate experimental results of lava's velocity. The students were taught the tsunami, tectonic plate, earth's magnetic field, volcano eruption, climate changes, sun's radiation, and green house's effect topic. In the experimental groups Guided Inquiry Laboratory (GIL) model was used while the Regular Laboratory Activity (RLA) was used in the control class. The experimental class was exposed to GIL for a period of seven weeks. The researchers trained the other lecturer in the experimental groups on the technique of the GIL before the treatment. Pre-test was administered before treatment and a post-test after seven weeks treatment. The instrument used in the study was Scientific Abilities Performance Evaluation (SAPE) to measure student's scientific abilities. The instrument was pilot tested to ascertain the reliability. The reliability coefficient α was 0.76. Experts ascertained their validity before being used for data collection. Data was analyzed using t-test and gain score. Hypotheses were accepted or rejected at significant level of 0.05. The results of the study show that GIL resulted in higher improvement than RLA. The researchers concludes that GIL is an effective strategy, which physics lecturer should be encouraged to use and should be implemented in physics education programs.

Key words: *Scientific ability; guided inquiry laboratory (GIL); Regular Laboratory Activity (RLA)*

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INTRODUCTION

Scientific abilities are fundamental in conducting experimental science. Most of students of physics education program are not familiar with how to conduct experimental science or they may believe that they do not know enough about scientific abilities. Indeed, student' misconceptions and inaccuracies regarding randomization, sample size, and proper controls have been described at the college level (Anderson-Cook and Dorai-Raj, 2001; Hiebert, 2007), at the graduate-level (Zolman, 1999), as well as in professional publishing in life sciences (Festing, 2003). However, by using a inquiry model, students can become engaged in the scientific abilities and, in turn begin to think deeply about experimental science.

Levels of inquiry for science learning and later explicated the associated learning sequences. Wenning (2005, 2010) presented that by systematically addressing the various of inquiry levels. They are Inquiry discovery learning, interactive demonstrations, inquiry lessons, inquiry laboratory, and hypothetical inquiry. Lecturers would help students develop a wider range of intellectual and scientific abilities. Herron (1971) and Wenning (2011) classified the inquiry laboratory in three types based upon degree of sophistication and locus of control; guided inquiry laboratory, bounded inquiry laboratory and free inquiry.

The use of inquiry laboratory is hallmark of outstanding earth and space science lecturers or teachers. Earth and space science lecturers or teachers who use this approach develop within their students an understanding that science is both a product and a process. Not only act the students of these lecturers or teachers learn the rudimentary knowledge and skills possessed and employed by scientists, they also learn about the earth and space science (Pyle, 2008). There are many reasons why established in service earth and science lecturers or teachers fail to teach using inquiry laboratory. Among these reasons is that earth and space science teachers often do not themselves possess a holistic understanding of the scientific science. This in all likelihood stems from the nature of traditional earth and space science teaching and the Regular Laboratory Activity (RLA) at the university level that commonly uses a didactic teaching by telling approach. A GIL is the level of inquiry practice. Inquiry laboratory is generally will consist of students more or less independently developing and executing an experimental plan and collecting appropriate data. These data are then analyzed to find a law a qualitative relationship among variables for the seven topics courses. We used GIL for improving scientific abilities because the topics are very difficult to find precise relationship among variables. Wenning (2011) described that in inquiry Laboratory, students establish empirical laws based on measurement of experiment variables (work collaboration used to construct more detailed knowledge). This inquiry laboratory approach is not to be confused with the traditional "cookbook" laboratory (Regular Laboratory Activity/RLA) activity. The distinction between the Regular Laboratory Activity (RLA) and true inquiry oriented laboratory is presented on Table 1.

Table 1. Distinction between the Regular Laboratory Activity (RLA) and true inquiry oriented laboratory (IL).

No.	RLA	IL
1	are given step-by-step instructions requiring minimum intellectual engagement for the students.	are given questions requiring ongoing intellectual engagement using higher-order thinking skills (HOTS) making for independent thought and action.
2	student's activities is focus for verifying information previously communicated in class.	student's activities is focus for collecting and interpreting data to discover new concepts, principles, or empirical relationships.
3	students execute imposed experimental designs that tell students which variables to hold constant, which to vary, which are independent, and which are dependent.	Students create their own controlled experimental designs; require students to independently identify, distinguish, and control pertinent independent and dependent variables; promote student understanding of the skills and nature of scientific inquiry.
4	rarely allow students to confront and deal with errors, uncertainties, and misconceptions; do not allow students to experience blind alleys or dead ends.	commonly allow for students to learn from their mistakes and missteps; provide time and opportunity for students to make and recover from mistakes.
5	employ procedures that are inconsistent with the nature of scientific endeavor; show the work of science to be an unrealistic linear process.	employ procedures that are more consistent with authentic scientific practice; show the work of science to be recursive and self-correcting.

We used scientific abilities definition from Etkina et all (2006) that consist of six of seven scientific abilities; (1) representing physical processes in multiple ways; (2) modifying a qualitative explanation; (3) designing an experimental investigation; (4) collecting and analyzing data; (5) evaluating experimental predictions and outcomes, conceptual claims, problem solutions, and models, and (6) communicating experimental results. We removed one scientific abilities about finding quantitative relationship because the earth and space topics are very difficult to find the quantitative relationship in teaching activity.

Several physics education programs little attention is given to how the processes of inqury laboratory (IL) should be taught. It is often assumed that the teacher candidates graduate from the programs of higher learning for understanding how to conduct inquiry laboratory and can effectively pass on appropriate concept and science abilities to their students. Inquiry laboratory processes, if formally addressed at all, are often treated as an amalgam of non hierarchical activities. There is a critical need to synthesize a framework for more effective promotion of inquiry laboratory processes among students at all levels.

This article presents how to improve student's scientific ability by using guided inquiry laboratory with examples from earth and space science topic that can help physical science lecturers promote an increasingly more sophisticated understanding of guided inquiry laboratory among their students.

GIL Implementation

As example for implementing GIL in this paper, we presented only one of the seven topics (tsunami, tectonic plate, earth's magnetic field, volcano eruption, climate changes, sun's radiation, and green house's effect topic). The topic is volcano eruption topic. In GIL, students were helped to find qualitative relationships among variables using controlled experiments. GIL has five stages of the inquiry levels learning cycle are as follows: *observation, manipulation, generalization, verification and application* (Wenning, 2011). ***Observation:*** The lecturer explored with asking students to conduct controlled experiments with volcano topic such that there is only one independent variable and three dependent variables. The lecturer gets students to define variables such as flow velocity of lava (V) and high of location (h), temperature (T), and density (ρ) prior to beginning the next phase. Students then independently design and perform experiments to find qualitative relationships between the velocity of lava (V) and high location (h) in one case, V and temperature (T), V and density (ρ) in the other case. ***Manipulation:*** The lecturer used a jigsaw approach to speed up the process of finding the final form of the empirical law for velocity of lava. The first group of students finds qualitative relationship between V and h. The second group finds relationship between V and T. The third group finds relationship between V and ρ. The students as a group is then are asked to predict the nature of the full qualitative relationship between all variables. There are several possibilities such as sum, product, quotient, and difference. The only relationship that satisfied the experimental findings (how relation V to h, T and ρ) is a product of terms. Students are then asked to assume this form of the function and find the values of any constants. By using data already available to them and a *physical interpretation of the data* (knowing that V was higher if *h was higher* or T was higher or ρ was lower). Testing of predictions based on this relationship would show it to be of the appropriate form. Students conducted controlled all variables of experiments, change one variable at same time while holding constants and allowing the other variables the vary to see the consequences of changes in the first. ***Generalization:*** Students made a steps of observations while changing the independent variable over a wide range, write their findings in words (no mathematic equations) on a whiteboard or other surface that can readily be shared with the entire group. The final physical relationship can then be predicted to be $V \sim hT(1/\rho)$. ***Verification:*** results comunicating, students find that other study groups have drawn the same conclusions from evidence. If there are any conflicts additional data are collected until such time as it is clear that nature does act uniformly and that differences that arise are likely the results of human error. This helps students to understand the nature of science. ***Application**:* The students completed a worksheet that includes multiple examples of flow velocity of lava (V) that explain why the V higher at lower location(h), for higher temperature (T) and for lower density (ρ).

METHOD

Quasi-experimental research Control Group Design was used (Robson, 2001). This is because there was non-random selection of students to the groups. Earth and Space Science (IPBA) classes exist as intact groups and Physics Department, Mathematics and Science Faculty, Universitas Negeri Surabaya (UNESA) authorities do not normally allow the classes to be dismantled and reconstituted for research purposes. (Borg & Gall, 1989; Fraenkel & Wallen, 2000; Madlazim and Supriyono, 2014). The conditions under which the instruments were administered were kept as similar as possible across the classes in order to control instrumentation and selection. The classes were randomly assigned to the control and treatment groups to control for selection. (Ary, Jacobs & Razavien, 1979).

Where O_1 and O_3 were pre-test score; O_2 and O_4 were the post-test score; X (=GIL) was the treatment where students were taught using GIL. Group 1 was the experimental class which received the pre-test, the treatment X and the post-test. Group 2 was the control group, which received a pre-test followed by the control condition and then the post-test. Group 2 was taught using T (=RLA). The Research design may be represented as shown in Figure 1. To analyze score improvement between experiment and control group was used gain score analysis. Madlazim and Sipriyono (2014) and Supriyono and Madlazim (2014) found that base on the gain score analysis can be inferred that the experiment design skills can be improved significantly.

O_1	GIL	O_2
O_3	RLA	O_4

Figure 1. Quasi Experiment Research Design.

The unit of sampling was the sixth semesters of physics education students of Physics Department, Mathematics and Science Faculty, State University of Surabaya (UNESA). This means therefore that all students of each group have been considered that have not studied the seven topics. The researchers visited the groups to ascertain that they were suitable for research. During the visit the researcher established that there were trained other lecturer in the classes and also obtained information on class composition and learner characteristics from Department records. The sample size of two selected group of the three classes in the division were obtained. Group 1 (Experimental group) N= 40 and group 2 (Control group) N=40. Therefore, the sample size in the research was 80. Fraenkel and Wallen (2000) recommend at least 30 subjects per group. Hence this number was adequate for the study.
The scientific abilities instruments adapted from Etkina et all (2006), Karelina and Etkina (2007) and Science Pioneers (http://www.sciencepioneers.org/sites/default/files/documents/Experimental Design vs ScientificMethod_0.pdf) and modified was used to measure the students' performance. It contained 20 indicators with a maximum score of 80. The instrument was given to three experts in physics education for validation. The test was pilot tested using a classe of physics education students of UNESA that was not included in the study but had similar characteristics as the sample classes. This ascertained the test reliability. The reliability coefficient was calculated using Kolen et.al.(1996). This method is suitable when performance scale can be scored. The reliability coefficient of the performance instrument was 0.82 which rounds of to α=0.76. According to Fraenkel and Wallen (2000), an alpha value of 0.65 and above is considered suitable to make group inferences that are accurate enough.
The content used in the class instruction was developed based on the revised 2011/2012 physics syllabus. A guiding manual was constructed for the lecturers involved in administering GIL that was used throughout the treatment period. The lecturers of the experimental group were trained by the researcher on how to use the manual. These lecturers taught using GIL on the seven topics for seven weeks. Before this period the pre-test were administered to Group 1 and Group 2. Treatment period was seven weeks for the seven topics as recommended in the syllabus. At the end of the treatment period a post-test was administered to both the groups.
For this study scientific abilities instrument was used to collect data. The pre-test was administered to group 1 and group 2. Then treatment took seven weeks and was given to the one experimental group after which post tests were administered to both the groups. The researchers scored the pre-tests and post-tests and generated quantitative data, which were analyzed. To analyze the data, we need the scores that students got from the both tests which are pre and post scores were was assessed by the administration of a diagnostic test for scientific abilities on the first and last day of control and experiment group; only students who took both pre-test and post-tests are part of the sample. The diagnostic instrument was the scientific abilities. This is the 20-items Liker-scale related to scientific abilities evaluation. The scientific abilities evaluation is almost entirely on a qualitative scale. The evaluation was adapted from Karelina and Etkina (2007) and Science Pioneers.

RESULTS AND DISCUSSION

To analyze data this study, we used SPSS 12 version. The results of the pre-test scores on SAPE for groups 1 and 2 showed a statistically significant difference 0.325, greater than 0.05 (Table 1 and Table 2). This means that the value was large, and therefore the obtained difference between the sample means is regarded as not significant. This indicated that the groups used in the study exhibited comparable characteristics. The groups were therefore suitable for the study when comparing the improvement effects of GIL and RLA on scientific abilities. The results of the pre-test scores on SAPE for groups 1 and 2 showed a statistically significant difference 0.325, greater than 0.05. This means that the value was large, and therefore the obtained difference between the sample means is regarded as not significant. This indicated that the groups used in the study exhibited comparable characteristics. The groups were therefore suitable for the study when comparing the improvement effects of GIL with RAL for the seven topics.

Table 1. Pretest analysis

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pretest	Experiment (GIL)	40	1,6990	,08686	,01373
	Control (RLA)	40	1,7199	,10067	,01592

Table 2. t-test for Equality of Means

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pretest	Equal variances assumed	,418	,520	-,991	78	,325	-,02083	,02102	-,06269	,02102
	Equal variances not assumed			-,991	76,360	,325	-,02083	,02102	-,06270	,02104

To analyze differences of the two means of the experiment and control group, post-test scores used the Wilcoxon W Test as shown in Tables 3 and 4 which show significance of (0.000) - less than 0.05. This indicates that there are significant differences in mean post-test scores between the experimental and traditional group. Based on the mean (average), the average grade post-test experimental group scores are greater than the average post-test scores of a control group. The results indicate that the students' scientific abilities of experimental group are better than the students' control group.

Table 3. Post-test analysis

Group Statistics

group		N	Mean	Std. Deviation	Std. Error Mean
Posttest	Experiment (GIL)	40	3,0365	,04757	,00752
	Control (RLA)	40	2,6554	,09113	,01441

Table 4. t-test for Equality of Means

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pos t-test	Equal variances assumed	13,503	,000	23,446	78	,000	,38109	,01625	,34873	,41344
	Equal variances not assumed			23,446	58,786	,000	,38109	,01625	,34856	,41361

CONCLUSION AND RECOMMENDATION

The results of the study show that GIL resulted in higher improvement than RLA. The researchers concludes that GIL is an effective strategy, which physics lecturers should be encouraged to use and should be implemented in physics education programs.

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