Argument-based inquiry lab activity on microbiological water analysis for pre-service biology teachers

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Abstract. Lab activity is a critical part of microbiology course for pre-service biology teachers. So far, cookbook microbiology practices were used to be applied instead of inquiry and argument-based activities. Scientific argumentation is not only for socioscientific issues, but also for lab activities for improving students scientific argumentation skills. The aim of this study was to investigate the students’ learning experience and scientific argumentation skills in a microbiology argument-based inquiry lab activity. The most probable number (MPN) methods were designed to analyse drinking water samples by detecting the presence of coli fecal bacteria. The observation method was used to assess learning experiences for the students. Meanwhile, scientific argumentation skills were assessed by using argument level criteria from students worksheets and lab report. The lab activity was following 8 steps: 1) introducing the problems and investigation questions; 2) formulating initial group arguments and hypothesis; 3) designing and conducting the experiment; 4) analyzing data and formulating group arguments; 5) engaging in argumentation session 6) writing lab report 7) doing peer-review; and 8) writing revision and evaluating the report. The results showed that the argument-based inquiry lab activity improving students scientific argumentation, especially in making data as evidence for their claims. The students also responded that the activity made them have more understanding and interest in microbiology.

1. Introduction

Lab activity is a critical part of science learning and playing important role in science education and for prospective science educators including pre-service biology teachers [1]. Science classes in higher education usually have two separated components – lecture and laboratoty sections. Laboratory activity allows students to be involved in hands-on use of equipment and investigative methods in order to improve students’ science process skills, understanding the nature of science content cognitions and attitudes [2]. One of important learning aims for lab activity is to provide students with practice and experience in designing experiments [3] and it can be trained during inquiry oriented lab activities. Therefore, inquiry oriented lab activities should be applied in most lab courses for prospective science teachers.

Argumentation in science teacher education is considered to be promoted as central elements of science education because it is the fundamental role in the practice of science in scientific communities [4]. A plentiful number of studies have reported the using of argumentation in science classes [5-8].
the studies, they showed that so many science teachers have problems integrating scientific argumentation and inquiry in their class, in order to help their students understand the development of important concepts in science. Although argumentation has been considered to have important role in science education, it is rarely used in science courses or laboratory activities [5, 7, 9]. Scientific argumentation is not only for socioscientic issues, but also for lab activities for improving students scientific argumentation skills.

On the other hand, in the study of Kim and Song [10] in which they investigated the arguments of students engaged in scientific inquiry activities, it was observed that students had improved their argumentation process. Watson, Swain, and McRobbie [11] found results contrary to Kim and Song. In the study, the quality and quantity of the arguments of scientific inquiry were low. It was believed that this study could help individuals with difficulties in scientific inquiry, argumentation, and their use in the classroom by providing information about scientific inquiry and argumentation. Although science laboratory practices aim to provide concrete experiences, to activate experiential learning, to increase student knowledge, and to provide meaningful and permanent learning, the “cookbook” approach in traditional laboratory practices hinders science classes from reaching their goals [1, 12, 13].

One of the methods suggested for increasing student achievement in laboratory instruction in this study is Argument-based Inquiry Lab Activities that to be developed based on the model of Argument Driven Inquiry (ADI). ADI is a method that has many similarities to models such as Argument-based inquiry that using Science Writing Heuristics (SWH) and the 5E learning cycle models, and provides students with the opportunity to construct their own explanations and to share their ideas while socializing in small groups or during in class discussions. It creates a classroom atmosphere that provides a cultural process for the teaching of science [7]. This model is designed to make laboratory instruction more informative and to plan scientific inquiry which includes argument development through research questions [7, 13]. This method gives students an opportunity to generate an argument in the direction of their own questions, to assert methods for finding answers to those questions, and to design the research through group work. It also provides students with an opportunity to evaluate the validity and reliability of their data, and to spend time on key concepts and ideas in order to form a deep understanding [7, 13]. So far, cookbook microbiology practices were used to be applied in microbiology course instead of inquiry and argument-based activities. The aim of this study was to investigate the students’ learning experience and scientific argumentation skills in a microbiology argument-based inquiry lab activity.

2. Method
This study was conducted in a microbiology laboratorium at a biology education institute in Cirebon, West Java. The study involved 36 students who engage the microbiology course during the 5th semester. The participants following the instruction in microbiology lab activities according to Argument-based Inquiry Lab Activities developed in this study in the topic of microbiological water analysis using The Most Probable Number (MPN) Methods.

The MPN methods were designed to analyse drinking water samples by detecting the presence of coli fecal bacteria. The lab activity was following 8 steps: 1) introducing the problems and investigation questions; 2) formulating initial group arguments and hypothesis; 3) designing and conducting the experiments to gain data; 4) analyzing data and formulating group arguments; 5) engaging in argumentation session 6) writing lab report 7) doing peer-review; and 8) writing revision and evaluating the report. The instruments used to collect data were Observation Sheets, Argument Level Criteria and Scientific Argumentation Skills Test. The observation method was used to assess learning experiences for the students. Meanwhile, scientific argumentation skills were assessed by using Scientific Argumentation Test and Argument Level Criteria from student’s worksheets and lab report. The data from the observation result and argument levels analysed descriptively.
3. Results and discussion

3.1. Students’ learning experience

The result of the observation showed that the implementation of all the stages of the argument-based inquiry lab activities was followed by almost all of the participants (90.2% in average of 4 observers). Every stage of the program was designed to make the participants involved in argument-based and inquiry-oriented lab activities.

The first stage was introducing to the problem and investigation questions. In this stage, the students gave full attention to instructor opening the activity and introducing the problem. The students also responded the aperception questions, followed the grouping instruction and task distributions given by the instructors. The aperception questions were mostly about the requirements of drinking water and how to determine them. While the investigation question was “Which of the water samples that microbiologically adequate as drinking water?”.

In the second stage, students discussed the problem and formulated a hypothesis as part of initial argument. They then wrote the argument in their own worksheets as the guide to carry out the experiments. The third stage was the opportunity for the students to plan and perform the experiments in order to gain the data. The MPN methods were implemented in this stage. The MPN methods consisted of 3 steps: presumptive, confirmed and completed tests. At the end of this stage, students had already gained data to be analysed to answer the investigation questions.

In the forth stage, the students analysed the data and formulated group arguments according to the investigation question. Then, in the fifth stage they conducted argumentation session. In this stage, each group presented their own arguments and criticized others’, while they evaluated the components of the arguments such as the claim content, the quality of the data as evidence and the strength of the rationale in evidence explanation. In the sixth stage, students wrote the lab report of the investigation. While in the seventh stage, students conducted peer review of the lab report. They evaluated and gave suggestion to each other in order to make better report. And the last stage was the time when students revised the lab report to be evaluated by the instructor.

All of the stages followed by the students along this program, allowed them to involved in an inquiry-oriented and argument-based investigation while they learn to write a lab report using argumentative style. So, they have the experience to be implemented when they teach science as the teachers in the future.

3.2. Scientific argumentation level during argument-based inquiry lab activities

The quality of arguments in the process of the lab activity can be seen from two products of group arguments in the beginning of the activity as an initial argument; and final argument that formulated after the investigation.

| Table 1. The amount of each argument level. |
|-------------------------------------------|
| Level | Initial Argument | Result Argument |
|-------|------------------|-----------------|
| Level 1 | -                | -               |
| Level 2 | 50%              | 16.67%          |
| Level 3 | 50%              | 66.66%          |
| Level 4 | -                | -               |
| Level 5 | -                | 16.67%          |

Tabel 1 shows that the quality of initial arguments mostly in the middle, in level 2 and 3. Initial arguments means arguments that students made before conducting the experiment. So, they made the arguments based on their prior knowledge about microbiological drink water quality. While result arguments have better quality, mostly in level 3 (66.7%) and there are some much better arguments in level 5 (16.7%). Eventhough there were arguments still in the level 2 (16.7%), but it is much reduced.
This means that students can make better quality of arguments after having an investigation, rather than only using prior knowledge from second-hand resources of data as the evidence. They made much better rational as the explanation of the evidence to support their claims.

The improvement of the quality in making argument for students was gained from the students’ experiments result that gave them primary data used as the higher quality of evidence supporting their claims and making better rational for the explanation. The result was in line with Katchevich’ research that showed inquiry experiments are potential platform to allow students formulating better arguments by the discourse that rich in arguments in compare to a confirmatory experiments [14].

Figure 1 shows the quality of individual arguments made by students in the lab reports. It can been from the figure that the most arguments are in level 4, level 5 and level 3, while there’s no arguments in level 1 and 2. This means that the quality of the lab reports are in the middle and higher level. The students in this study have the ability to make good arguments in lab reports. It seems that Argument-based inquiry lab activity approach is used to help students find a richer understanding of the argument and how to present the argument in the lab report. This result is corresponding with the research result of Hand et al. [15] and Ozdem et al. [16]. In the Hand’s research, the result shows that the treatment group with argument-based laboratory investigation in general chemistry course, gained significantly higher quality in argumentation and understanding of science concepts. While Ozdem research result showed that inquiry-oriented laboratory activities that enriched with critical discussion provides discourse opportunities to support argumentation for pre-service science teacher in order to promote argumentation in their future science classrooms.

The result of scientific argumentation skills test is provided in the figure 2.
The results in figure 2 showed that in the pre test, the highest score was in the aspect of claim while the lowest was backing. But, in the post test, the highest score was in the aspect of data and the lowest was still in backing. This means that before the program, students have the highest ability in making claims than other components of arguments, such as providing data, warrant and backing. Since they have experienced the argument-based inquiry lab activity, all the aspects were improved. Specifically, in making data, the improvement was beyond making claim. This result show that the inquiry-oriented and argument-based lab activity help students in providing data as the evidence to support their claim. Primary data from experiment give special Besides, the significant improvement of making warrant and backing shows that this findings are along with the research result from Land [17] that recognizing the relationship between the knowledge and the activities performed that can produce more and better information, adding to them having more generally appropriate data in the context of limited awareness. The learning environment in which open inquiry experiments are conducted consists of the characteristics of encouraging the construction of arguments in which the student is at the center of the process. The nature of the task in open inquiry experiments encourages students to construct arguments as individuals or in small groups. The argument combines evidence from laboratory observations with explanations that are usually based on classroom lessons or are constructed during group discourse on concepts they learn outside the classroom. In addition, students have time to discuss these concepts, so that the potential assignment can be really expressed [9, 14].

4. Conclusions
The argument-based inquiry lab activity improving student’s scientific argumentation, especially in making data as evidence for their claims. The students also responded that the activity made them have more understanding and interest in microbiology. In terms of teacher education, there are important implications that arise from this study. Teachers need to have argument-based inquiry approach experiences if they will implement such an approach in their classroom. The shift from traditional approach to inquiry is required when using argument-based inquiry in their classrooms.

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