Prospective biology teachers’ critical thinking skills in microbiology argument-based inquiry laboratory activities

E Roviati1,2*, A Widodo1, W Purwianingsih1 and R Riandi1
1Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Bandung 40154, Indonesia
2Program Studi Pendidikan Biologi, Institut Agama Islam Negeri Syekh Nurjati Cirebon, Jl. Perjuangan By Pass Sunyaragi, Cirebon 45135, Indonesia

*evi1rovati@gmail.com

Abstract. Argumentation in science education have been realized to have connections with many benefits including critical thinking skills. This study explored the implementation of argument-based inquiry activities in microbiology laboratory course and how the implementation may improve students critical thinking skills. The subject of this research was the fifth semester students of a biology teacher educational institution in Cirebon. The data collected were the students’ critical thinking skills using a set of critical thinking skills test in microbiology lab course. The result showed that the students’ participation in the microbiology argument-based inquiry laboratory activities significantly improved the critical thinking skills of the students. The aspects of the critical thinking skills that influenced the most by the program was developing and maintaining a position in an issue by analyzing, evaluating and producing explanations.

1. Introduction
Argumentation has been realized to have connections with many benefits in science education, such as enhancement of conceptual understanding, improvement of academic performance, advancement of passion in inquiry and development of critical thinking skills [1]. The importance of argumentation in science education has been highlighted extensively in recent years [2,3]. Educators who wish to develop thinking skills of their students may consider their efforts to be largely successful if students become adept at advancing, criticizing, and defending claims in reasoned discussions with peers. Yet the psychological literature has contributed little to our understanding of developing skills [4].

An argument is a statement with justification [5]. The terms argument and argumentation can be understood as a product or process. One can build arguments as a product to support a claim. While the dialogical process in which two or more persons engage in conflicting claims may be referred to argumentative discourse or argumentation as a process [4].

Generating arguments means showing conditions when an argument can not apply and looking for flaws in an opposing argument to deny it indicates the importance of argumentation for students [6,7]. Scientific argumentation is a special case when dialogue is directed at the coordination of evidence and theory to improve explanations, models, predictions or evaluations [3, 8]. The use of scientific argumentation is not only for socioscientific issues, but also for lab activities for improving student’s scientific argumentation skills.
According to Toulmin Model [9], the structural components of an argument include claims, data, backing, warrants, rebuttal and qualifier. This model has been the basis for evaluating the quality of an argument in terms of the presence or absence of these structural components. Some researchers suggest that a simple argument of the argumentative element does not accurately reflect the persuasive quality of an argument, rather on an evaluation framework that should pay attention to the combination of elements [10]. The use of rebuttal represents a better quality argument and demonstrates capacity for higher level arguments.

Critical thinking has become a hot topic in education, especially science education [11-12]. Critical thinking is one of the 21st century skills and competencies to be developed by new millennium learners [13]. To be a critical thinker is to have an intellectual virtue, a disposition raised in rational skillful activity, reflective thinking about what to believe or do [14]. Critical thinking, therefore, interprets critically and evaluates arguments, and builds the arguments of pros and cons to test the confidence of position or decision power. Therefore critical thinking exercises include skills in argument management as one of its components [4]. The main characteristic of critical thinking in deciding about beliefs is an argument, by testing the arguments of others and developing their own arguments. Basically, arguments are an attempt to prove or maintain a conclusion [15].

Laboratory activities are an important and necessary part for science education, where students can demonstrate their high-level thinking skills [16]. Students can generate scientific arguments in laboratory activities by seeking answers to open investigation questions given to them through experiments. In order to encourage attention to critical thinking, teacher should focus on developing students’ epistemological beliefs, applying active learning using real-life situations that deal with problems and encouraging interaction between students to enable them to speak and share different views. Students should be given time to deal with problems, forming good questions and considering hypotheses and thereby formulating good arguments [7,8].

Improving the quality of science learning in schools is carried out through various strategies, including improving teacher welfare by introducing teacher certification programs and conducting evaluations and reviews of teacher education programs to improve the quality of prospective science teachers [10]. In fact, biology teacher students have little knowledge of the arguments and their application in biological learning, in addition they produce low quality arguments [17]. 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.

Argument-based inquiry lab activity in this study is a laboratory activity program designed to give students the opportunity to practice improving the quality of their arguments as well as familiarize themselves with inquiry laboratory activities. The program is an adaptation, modification and synthesis of the Argument-Driven Inquiry model [18] and Argument-Based Inquiry using The Science Writing Heuristic approach [19]. This study explored the implementation of argument-based inquiry activities in microbiology laboratory course and how the implementation may improve student’s critical thinking skills.

2. Method
This study employed a quantitative experimental method using a randomized pre-test-control group control design [20]. The independent variable in this research is the application of Argument-Based Inquiry Laboratory Activities, while the independent variable is critical thinking skill. The data collected were students' critical thinking skills using critical thinking skills tests developed by researchers with reference to 6 critical thinking indicators synthesized based on its characteristics formulated by Fascione [21], Fisher [22] and Ennis [14]. The test was performed before the program as a pre test, and after the program as a post test.

The study took place in a microbiology laboratory of a biology teacher educational institution in Cirebon. The subjects of this research were the fifth semester students, consisting of 36 students in the experimental class and 34 students in the control class. The participants in the experimental group
followed the lab activity by applying Argument-Based Inquiry Laboratory Activities, while the control group performed the microbiology practice using a cookbook manual.

The data collected were then analyzed using statistical tools to reveal the significance of the average difference of the two test results of critical thinking skills between experiment and control class, and a more in-depth analysis for each indicator of critical thinking to reveal which of the 6 aspects that influenced the most by the program.

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This study attempted to explore the implementation of the Microbiology Argument-Based Inquiry Laboratory Activity program to the 5th semester students majoring in biology teacher education. The program consisted of 4 topics with 8 steps each. The first topic was about antimicrobial sensitivity test, while the second topic was about microorganisms in our environment, the third topic was on food microbes and the fourth topic was the microbiological test of drinking water.

3. Result and discussion

3.1. Students critical thinking skills

The first result of the study taken from the critical thinking test was the overall result of students' critical thinking skills in the experimental and control groups. The data of the scores can be seen on figure 1.

Figure 1 shows that the average post test score of the students in both experimental and control groups were higher than their pretest score. This means that the critical thinking skills of students in both classes were enhanced after following microbiology lab activities. However, the enhancement of the experimental class seemed to be different.

![Figure 1. The results of critical thinking skills of the experimental and control class.](image)

Figure 1 shows that in the experimental class, the mean pre test of critical thinking skill was 37.24 and the control class was 28.05. Meanwhile, the mean score of postes of critical thinking skill of the experimental class is 64.35 and the control class is 40.41. From the test result of critical thinking skill of experiment and control class, it can be obtained the N-gain of each class. N-gain experimental class included in medium category (42.91) and much higher than control class (17.03) which belongs to low category.
From the result, it can be seen that inquiry-based learning approaches have significant effects on students’ critical thinking skills. This result is along with the study in science and technology learning and neuroanatomy course supported with the guided activities developed in line with the IBL approach that have significant effects on students’ critical-thinking skills [23, 24].

Meanwhile, the statistical test on the N-gain value of critical thinking skills of the experimental and control class to find out the significance of the mean difference of both can be seen in table 1.

Table 1. The result of normality, homogeneity and difference test of the mean of critical thinking skills gain in experiment and control class.

| Types of tests        | Class            | Sig.  | Note          |
|-----------------------|------------------|-------|---------------|
| Normality             | Experiment       | 0.321 | Normal        |
|                       | Control          | 0.156 | Normal        |
| Homogeneity           | Experiment & control | 0.041 | Not homogen   |
| Independent samples (t) Test | Experiment & control | 0.000 | significantly different |

Table 1 shows the results of the normality and homogeneity tests of the two classes, indicating that the N-gain values of both classes are normal, but not homogeneous. Thus, the difference test of the two average N-gain used was the non-parametric statistical test, the Mann-Whitney test. From the test obtained sig value. 0.000 which means that both N-gain average critical thinking skills of experimental class and control class differ significantly.

From the result, it perceived that the students in the argument-based inquiry lab activity group had significantly higher critical thinking skills score. This finding align with Stephenson study in which the Science Writing Heuristic chemistry laboratory approach shows efficacy in improving students’ critical thinking skills [25]. The findings also provide more evidence to confirm the studies conducted in the field of applying argumentation in laboratory and inquiry activities in science class, such as Argument-Driven Inquiry model [18, 19, 26].

3.2. Critical thinking skills of each indicator

Figure 2. The results of critical thinking skills of each indicator.

Figure 2 shows the data of critical thinking skills of the students from every indicator. The indicators are: 1) to assess the acceptability of an information by considering the credibility of the source, its evidence and its claims; 2) to identify the elements in the case under consideration in the form of conclusions, reasons and assumptions; 3) to assess/consider/evaluate the quality of various kinds arguments, including whether reasons, assumptions and evidence are acceptable; 4) to produce
arguments and present them; 5) to develop and maintain a position in an issue by analyzing, evaluating and producing explanations; and 6) to plan the experiment by assessing the procedures and design of the experiment.

Figure 2 shows that the most notable improvement of critical thinking skills in the experimental class was on indicator 5, which was to develop and maintain a position in an issue by analyzing, evaluating and producing explanations; and then followed by indicator 1, namely assessing the acceptability of an information by considering the credibility of the source, the evidence and its claims. While the most critical aspect of critical thinking skills both in the pre test and the post test was on the 4th indicator, which is to generate the arguments and present them.

The findings revealed the facts that the discussion and argumentation in laboratory activity can improve the ability of students to develop and maintain a position in an issue by analyzing, evaluating and producing explanations. This can be benefits when they have questions or problems to be answered and solved while they have the data to be utilized. In the argumentation session, they can analyze, evaluate and produce explanation about the methods, results and phenomena connected to the investigation questions. This findings are in line with results of the studies applying argument-driven inquiry in science learning by several experts [18, 19, 26].

4. Conclusion
The result of this study showed that the students’ participation in the microbiology argument-based inquiry laboratory activities significantly improved the critical thinking skills of the students. The aspects of the critical thinking skills that influenced the most by the program was developing and maintaining a position in an issue by analyzing, evaluating and producing explanations; and assessing the acceptability of an information by considering the credibility of the source, the evidence and its claims.

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