Enhancing Scientific Inquiry Literacy of Prospective Biology Teachers through Inquiry Lab Project in Microbiology

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Abstract. The implementation of the inquiry laboratory based project to enhance scientific inquiry literacy of prospective biology teachers in Microbiology course has been done. The inquiry lab based project was designed by three stages were debriefing of basic microbiology lab skills, guided inquiry and free inquiry respectively. The Study was quasi experimental with control group pretest-posttest design. The subjects were prospective biology teachers consists of 80 students. The scientific inquiry literacy instrument refers to ScInqLiT by Wenning. The results showed that there was significant difference of scientific inquiry literacy posttest scores between experiment and control (α 0,05) and was obtained N-gain score was 0.49 (medium) to experiment and 0.24 (low) to control. Based on formative assessment showed that development of student’s scientific attitude, research and microbiology lab skills during conducting project were increased. Student’s research skills especially in identification of variables, constructing a hypothesis, communicating and concluding were increased. During implementation of inquiry project also showed that they carried out mind and hands-on and so collaborative group investigation lab activities. Our findings may aid in reforming higher-education, particularly in microbiology laboratory activities to better promote scientific inquiry literacy, scientific attitude, research and laboratory skills.

1. Introduction

Inquiry is the essence of science education. Inquiry is the process of finding out by searching for knowledge and understanding. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world [1]. Scientific inquiry is the element of science literacy. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work [2]. Scientific inquiry is a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions [3]. Scientific inquiry is an extension of the scientific method, that applied in action in learning science and life [4]. Scientific inquiry literacy is the person ability of understanding and applying science concepts in inquiry process or scientific investigation [5]. Scientific inquiry literacy is the component of science literacy which has to be possessed of every citizens.
The quality of meaningful teaching and learning process in higher education should have the following characteristics: 1) invite the curiosity of students; 2) challenge students to learn; 3) activate mental, physical and psychological; 4) facilitate lecturers in managing the class; 5) develop student creativity; and 6) developing students' understanding of the content learned. To accommodate the principles of learning at higher education, particularly for the adult education, the experiential learning is often used as learning model, that leads to autonomy and self-directed learning [6].

Project-based learning is an innovative learning model, which emphasizes contextual learning through complex activities [7,8,9,10]. The focus of learning lies in the core concepts and principles of a discipline, involving learners in problem-solving investigations and the activities of other meaningful tasks, giving learners the opportunity to work autonomously for constructing their own knowledge, and reaching its peak by producing tangible products [11]. Syntax of project based learning model has been developed by The George Lucas Educational Foundation [12]. Project based learning is one type of inquiry based learning model. The main goals of inquiry-based learning are: 1) developing students' curiosity and motivation to learn the principles and concepts of science; 2) developing students' scientific skills so they can work like a scientist; 3) familiarize students to work hard to gain knowledge. In principle, inquiry instruction helps students to formulate questions, seek answers or solve them to satisfy their curiosity and to help their theories and ideas about the world. Inquiry based learning also aims to develop thinking skills [2]. Intellectual abilities that is expected in the inquiry-laboratory based learning is integrated skills as follows: 1) measure metric (standard unit), 2) build empirical law based on proof and logic, 3) designing and conducting scientific investigations, and 4) using technology and mathematics during investigations [13]. The American Association for the Advancement of Science recommended that science educators have to promote independent learning, engage students in experimental design and execution, emphasize science as it is practiced, and promote scientific communication skills [14, 15]. The science education researcher also emphasizes the importance of application of inquiry-based learning in biology at university level [16].

There have been many research reported on project-based learning and inquiry in science, but there are still few reports of scientific inquiry particular in microbiology lab activities. This study is expected to provide meaningful information for debriefing of scientific inquiry for biology teacher candidates in Institute of Teachers Education (LPTK).

2. Experimental Method
This study used a quasi-experimental design, with the control group pretest-posttest design [17]. The subjects are prospective biology teachers who enrolled in Microbiology. Study was carried out at one of public Institute of Teacher’s Education (LPTK) in Bandung. The sum of subjects were 80 students (experimental was 42 and the control was 38 students). The study was conducted in three stages as follow: 1) debriefing of basic microbiology lab skills, such as making of sterilized media, bacterial staining technique, isolation and enumeration of microbes, and bacterial identification; 2) guided inquiry for debriefing of scientific inquiry skills; and 3) designing and implementing of microbiology project (free inquiry); called as “Mini-research” project. The scientific inquiry literacy of prospective biology teachers was measured by a well-chosen multiple choice test refers to the ScInqLiT instrument [5]. The student’s research and laboratory skills, and scientific attitude development were assessed by formative assessment during the learning process. Data Analysis used empirical statistical approach and Normalized gain (N-gain) score category [18].

3. Result and Discussion
Based on the research results in measuring of scientific inquiry literacy of prospective biology teachers was obtained recapitulation of pretest-posttest data (Experiments and control class) as shown in Table 1.
Table 1. Recapitulation of Pretest-Posttest scores of scientific inquiry literacy

| Parameters                   | Control | Posttest | Experiment | Posttest |
|------------------------------|---------|----------|------------|----------|
| Sum of students              | 38      | 38       | 42         | 42       |
| Score averages               | 32.84   | 47       | 35.29      | 61.81    |
| Deviation standard           | 5.69    | 10.47    | 8.51       | 10.44    |
| Minimum scores               | 18.00   | 23.00    | 16.00      | 37.00    |
| Maximum scores               | 47.00   | 68.00    | 42.00      | 82.00    |
| N-gain                       | 0.24    |          | 0.49       |          |
| Normality test               | 0.43    | 0.97     | 0.50       | 0.59     |
| Homogeneity test             | Normal  | Normal   | Normal     | Normal   |
| Two difference t’ Test of scientific inquiry literacy posttest scores between experiment and control at α 0.05 | 0.00    |          |          |          |

Based on Table 1 shows that there is a significant difference between experiment and control posttest averages score at level significance α 0.05 ( t’ test 0.00 < 0.05). It indicates that inquiry lab project provides meaningful experience for prospective biology teachers for debriefing of scientific inquiry. Table 1 also shows that N-gain score is different between experiment and control class. N-gain of experiment class is 0.49 (medium category), while control is 0.24 (low category). It means that there is an increase in N-gain score in experimental higher than the control class. Furthermore, the comparison of N-gain score of scientific inquiry literacy for each indicators between experiment and control class is shown at Figure 1.

Based on Fig 1 indicates that the N-gain score between experiment and control class of scientific inquiry literacy of prospective biology teachers is different, particular in indicators of designing experiment procedures, identification and control variables and construct the hypothesis. Thereby the inquiry project-based learning has contributed to debriefing of prospective biology teachers to understand principles and procedures of scientific inquiry. During conducting microbiology project they were doing sciences as wells as scientists were doing research. This indicates that inquiry based projects provide meaningful learning experiences for prospective biology teachers, so suggest that they can design inquiry project-based learning at schools in the future.

Furthermore development of research skills of prospective biology teachers through formative assessment during implementation of microbiology project is shown at Table 2.

Table 2. Development of averages research skills scores of prospective biology teachers

| No  | Indicators                      | Guided inquiry lab 1 | Guided inquiry lab 2 | Free inquiry Lab |
|-----|--------------------------------|----------------------|----------------------|-----------------|
| 1   | Formulate the problems          | 77.38                | 80.00                | 80.71           |
| 2   | Ask questions                   | 76.90                | 77.86                | 79.52           |
| 3   | Identification of variables     | 76.90                | 81.67                | 82.14           |
| 4   | Control of variables            | 75.48                | 79.76                | 80.36           |
| 5   | Construct hypothesis            | 70.60                | 79.05                | 80.24           |
| 6   | Design procedures of investigation | 79.29              | 80.24                | 80.83           |
| 7   | Communicate results of investigation | 80.71              | 83.57                | 84.29           |
| 8   | Analysis and interpreted data   | 77.02                | 80.24                | 80.12           |
| 9   | Draw conclusion                 | 74.88                | 81.43                | 82.26           |

Averages 77.98 81.37 81.88
Figure 1. The comparison of N-gain scores scientific inquiry literacy between experiment and control class of each indicators

Based on data in Table 2 indicates that there is development of student’s research skills on each inquiry stages from guided inquiry to free inquiry. Thereby the inquiry-project based learning has contributed to debriefing of prospective biology teacher’s research skills. They engaged fully in designing and implementation of investigation. They learn content as well as practice for applying microbiological concepts to solve problems in everyday life. They learn to cultivate their own authentic research from individual work and then work collaboratively in small groups. Each student learns how to design scientific research, to produce meaningful products. This study is also carried out formative assessment through performance assessment of microbiology-laboratory skills of prospective biology teachers during both practicum and inquiry project activities. The data are shown at Fig 2.
Figure 2. Averages of student’s microbiology lab skills scores of each indicators

Based on Fig 2 shows that the averages of microbiology lab skills scores during the project implementation of prospective biology teachers is high enough. It means that the inquiry project-based learning has contributed to the debriefing of student’s microbiology lab skills especially in microbe enumeration, aseptic work and perform bacterial staining technique. It’s appropriate with research results of appearance of specific student’s microbiology laboratory skills through inquiry project-based learning in Microbiology course [19]. Thereby the inquiry project based learning has to develop for coaching laboratory skills. Furthermore through formative assessment is obtained data of student’s scientific attitude during microbiology project implementation. The data are shown at Figure 3.

Figure 3. Averages of student’s scientific attitude scores during project implementation
Based on Fig 3 shows that averages of student’s scientific attitude scores during the project implementation is high enough, particular in trust and openness as well as collaboration and disciplines. It means that the inquiry project-based learning in microbiology has contributed to build student’s scientific attitude that be needed for working and getting career in the future. And scientific attitudes also are an important belongs to every citizens, who are essential to work and to social life in the future. Furthermore it is necessary to convey the title of the group “Mini-research” inquiry-project were designed and implemented as shown in Table 3. Based on Table 3 indicates that the group project titles cover representing all areas of applied microbiology consists of health microbiology (4 groups), food microbiology (4 groups), environmental microbiology (3 groups) and industrial microbiology (3 groups). Group inquiry projects also produce various representative products such as: pure cultures of bacteria or fungi, packaging products such as skin ointment and fermented foods or beverages, and so posters. This product is very meaningful for both of scientific and general public community.

| Group | Inquiry Projects Titles                                                                 | Area of Microbiology | Representative products                  |
|-------|----------------------------------------------------------------------------------------|----------------------|-----------------------------------------|
| 1     | Utilization of guava leaf extract (*Psidium guajava*) to inhibit the growth of acne bacteria (*S. aureus*) | Health               | Pure culture, skin ointment, poster     |
| 2     | Effect addition of *Beta vulgaris* tuber extract to organoleptic value of goat milk yoghurt using inoculum of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* | Food Microbiology    | Goat milk yoghurt, poster               |
| 3     | Effect of *Rhizobium sp* inoculum concentration to greenpeal (*Phaseolus radiatus*) growth | Environmental Microbiology | Pure culture, liquid Bio-fertilizer, poster |
| 4     | Effect of Mengkudu juice (*Morinda citrifolia*) concentration to inhibit fungi growth of *Candica albicans* | Health Microbiology  | Pure culture, mengkudu Juice, poster    |
| 5     | Effect of lactic acid bacteria (LAB) concentration to organoleptic and save value of bread fermentation | Food Microbiology    | Bread product, poster                   |
| 6     | Effect of Incubation Temperature on Bioethanol Production of Banana peel Wastes with Acid Hydrolysis and Fermentation By *Saccharomyces cerevisiae* | Industrial Microbiology | Pure culture, bioethanol, poster       |
| 7     | Effect of biofertilizer *Azotobacter sp.* inoculum to Chillies Growth                   | Environmental Microbiology | Pure culture, liquid fertilizer, poster |
| 8     | Fermentation of *Guava, Mango and Tomatoes Juices Using Lactobacillus acidophilis as Probiotic Drink* | Food Microbiology    | Probiotic drink, poster                 |
| 9     | The Effects of *Saccharomyces cerevisiae* and *Aspergillus niger* Inoculum on Bioethanol Production from Pineapple Waste (*Ananas comosus*) | Industrial Microbiology | Pure culture, bioethanol, poster       |
| 10    | Production of Anti bacterial Ointment of *Chromolaena odorata* Leaf Extract to Inhibit *S. aureus* Growth | Health Microbiology  | Pure culture, skin ointment, poster     |
| 11    | Effect of Addition of *Azotobacter sp* to Straw Compost Mixture on Chilli Growth (*Capsicum Frutescens*) | Environmental Microbiology | Pure culture, liquid bio-fertilizer, poster |
| 12    | Fermentation of Pomegranate Juice using Probiotic Lactic Acid Bacteria (*Lactobacillus delbruecki* sub sp bulgaricus) | Food Microbiology    | Yoghurt pomegranate juice, poster       |
| 13    | Effect of Pinus Stem Bark Extract to inhibit *Staphylococcus aureus* growth              | Health Microbiology  | Pure culture, skin ointment, poster     |
| 14    | Effect of *Saccharomyces cerevisiae Inoculum Concentration on Bioethanol Production of Fermented Rotten Fruit | Industrial Microbiology | Pure culture, bioethanol, poster       |
4. Conclusion
Inquiry project-based learning in Microbiology has improved scientific inquiry literacy of prospective biology teachers. The Normalized gain score increased in medium category (N-gain = 0.49). Based on formative assessment showed that student’s scientific attitude, research and microbiology lab skills were increased. The student’s response to the programme reported that they gained greater experience and confidence in the scientific inquiry and laboratory skills activities. Our findings may aid in reforming of microbiology lab activities to better promote scientific inquiry literacy, scientific attitude, research and laboratory skills in the College. Based on research finding it may develop and implement the inquiry-project based learning for debriefing of prospective biology teachers in Institute of Teacher’s Education (LPTK).

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