Prospective biology teachers’ inquiry ability in free inquiry learning of molecular biology

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Abstract. The inquiry ability required by biology teacher in understanding and discussing the concepts of science in the classroom. This ability can be developed by prospective biology teachers during the learning process in college. Qualitative research method with one-shot case study design aims to assess the inquiry ability of 29 prospective biology teachers in free inquiry learning of molecular biology, especially on the DNA Isolation concept. The instrument of data collector is the inquiry ability test with five inquiry indicator, activity observation sheet and practice performance rubric. Data were analyzed by quantitative descriptive technique. The data analysis showed low performance test results for all indicators, moderate scores for inquiry activity and high scores for practice performance. Based on the results can be concluded that free inquiry learning is not maximal in shaping the prospective biology teachers’ inquiry ability; low category based on inquiry ability test results, moderate category for inquiry activity aspect and high category for performance of lab work aspect.

1. Introduction

Molecular Biology studies the molecular basis of every biological phenomenon [1]. Molecular Biology is undergoing rapid development when biological systems, especially the mechanisms of biological information transfer on bacteria and bacteriophages can be expressed, as well as the development of recombinant DNA technology (genetic engineering). However, the rapid development of Molecular Biology has not been followed by students’ understanding of this field. Biology students have no clear understanding of the difference between genes (DNA) and gene expression (mRNA/protein), and believe that genes exist in an organism or cell only when the gene is expressed [2]. The student thinks incompletely and misconception about the meaning of the transcription arrows in the representation of central dogma [3]. High school students have difficulty in learning Molecular Biology including difficulty in memorizing terms, remembering and understanding concepts, as well as connecting and applying the concepts. These difficulties relate to the nature of teaching materials, classroom learning, and textbooks used as major learning resources [4]. The survey conducted on Biology Education Program at Universitas Islam Riau in Pekanbaru which contracted the subject of Molecular Biology in Academic Year 2015/2016, obtained information that there are many abstract
concepts and foreign terms in Molecular Biology, there is no easy-to-understand teaching material, learning is not contextual, and there is no lab work.

Efforts to improve students’ understanding toward Molecular Biology should be done because they will assume the responsibility of facilitating the learning of biology topics in secondary schools. Relate to Molecular Biology is a knowledge that continues to grow rapidly and across many other disciplines of science, the ability of biology teacher candidates to observe, question, hypothesize, seek and process information, communicating findings and concluding absolutely necessary to understand Molecular Biology. One of the learning strategies that is expected to develop these abilities in building a good understanding of Molecular Biology is free inquiry learning, because in free inquiry learning students are trained to create their own problems based on their knowledge and work collaboratively by sharing and discussing with friends so students are motivated to learn intrinsically [5]. In addition, inquiry-based learning methods can improve learning motivation [6], cooperation among students [7], meaningful learning processes [8] and generate excitement for students while studying science [9]. The purpose of this study to describe the prospective biology teachers’ inquiry ability in free inquiry learning of Molecular Biology, especially on the DNA Isolation concept.

2. Method
This study was a pre-experimental study with one-shot case study design, i.e. treatment given to one group, then observations were made to the group members to assess the effect of the treatment [10]. The subjects of the study were 29 students of Biology Education Program at Universitas Islam Riau which contracted subjects of Molecular Biology. The concept of Molecular Biology discussed is DNA Isolation. Learning takes place with a free inquiry strategy and laboratory work method. Stages of free inquiry learning are orientation by lecturers, formulating problems, hypothesizing, collecting data to test hypotheses, communicating findings and concluding. Data were collected by test and observation techniques. The instrument of data collector used is the questions of inquiry ability, activity observation sheet and student worksheet, and rubric of laboratory work performance. Data analysis was done descriptively quantitative. The inquiry ability states the number of students who demonstrate an ability in accordance with the inquiry indicators of the total number of students, and grouped by categories: low ability (0-35%), average ability (36-71%) and high ability (72-100%).

3. Result and discussion
This section will describe the inquiry ability of students who are assessed by using the test of inquiry ability, observation sheet and student worksheet, and the rubric of lab work performance after free inquiry learning with lab work method. Discussion is also conducted on the use of some of these instruments in assessing the inquiry ability of students.

3.1. Inquiry ability test
The tests are designed based on theoretical content and techniques of DNA isolation combined in the form of narrative, the design of the lab work procedure, and the data in the table. The question number one (formulate the problem indicator) begins with a narrative of the lysis process as a first step in DNA isolation. In an isolated DNA experiment, three different chemicals were used for bacterial cell lysis. Furthermore, students are asked to formulate problems based on the narrative. To answer this problem, it is necessary precision students to see there are three different types of chemicals as variables, and based on these variables can be created questions. The question number two (hypothetical indicator) is student asked to create a hypothesis related to the formulation of the problem in question number one. The question number three (the indicator of collecting data to test the hypothesis) is students are asked to explain how to determine the concentration of chemicals (variables) to be used in an experiment based on an experimental design title. The question number four (indicator communicates the findings) is a table that presents three methods of DNA isolation, and each method consists of four different aspects. Students are asked to provide or findings information that can be extracted from the table. The question number five (indicator concluding) is
the student asked to make a conclusion based on the findings of question number four. The results of the test are shown in Table 1.

| Inquiry indicators              | Question number | Student number who answered exactly (%) | Categories |
|---------------------------------|-----------------|-----------------------------------------|------------|
| Formulate the problem           | 1               | 0                                       | Low        |
| Make a hypothesis               | 2               | 0                                       | Low        |
| Collect data to test hypotheses  | 3               | 14                                      | Low        |
| Communicates findings           | 4               | 35                                      | Low        |
| Concluding                      | 5               | 31                                      | Low        |

Table 1 shows that the ability of students in solving the problem of test is low category. Even for indicators to formulate problems and make a hypothesis no one student who answered correctly. Meanwhile, the questions for other indicators can be answered by a small number of students.

The difficulty in formulating the problem can be due to unaccustomed or untrained students observing the surrounding phenomena, responding to questions from lecturers, or analyzing the interesting points of learning resources during the lessons learned. Based on the observations, most of the lab work experienced by students is verification practice (following the procedure manual) and lecturers rarely ask questions in the learning process so that the ability to ask students is not trained and growing. The ability to formulate problems in inquiry learning is very important as the initiation of the learning process. NSTA states that the heart in inquiry learning is the ability to ask and formulate problems [11]. Problems or good questions will trigger students to actually learn, so they will understand more deeply about what is being learned. Lecturers can mobilize their creativity to provoke curiosity and lead students to a problem, for example by providing orientation questions, exposing students to a foreign phenomenon, or telling an interesting experience that leads the student to an important problem that becomes the learning objective.

Associated with improper students in formulating the problem, then the hypothesis proposed is also not appropriate. The hypothesis is a clear statement related to what will be investigated [12]. To create a hypothesis the student must have sufficient knowledge about the topic discussed. This knowledge can be obtained by students if they have a high interest in reading. Smith and Sotos et al. finds that one of the causes of difficulty is making hypotheses because of the limited literature that can be used by learners [13]. However, the authors argue not limited literature but the willingness of students to study the literature is still low. Most students are lazy to read references to materials for making tasks or materials for discussion, they rely more on search information via google and take snippets of information provided the facility. The step of making this hypothesis also does not appear (0%) in the Electrical-Magnetism inquiry study [14].

Only 14% of students can answer correctly for question number three. This situation reflects the ability of students in collecting data to test the hypothesis is low. This lack of ability can be attributed to the fact that unaccustomed and trained students read textbooks available in libraries, read research articles, try to summarize their reading, or mark important parts of their reading. This can lead to difficulties for students to collect data and information in order to test the hypothesis. Limited knowledge becomes the cause of difficulties to answer the test questions.

The ability to identify, compare, and analyze must have to answer the question number four so as to determine the important findings that can be taken from the given problem. As many as 35% of students can answer this question. Furthermore, in answer to question number five most students repeat the exposure of findings that have been answered in the previous problem, not make a conclusion. Only 31% of students succeeded in making the conclusion correctly.

Associated with the low of prospective biology teachers’ inquiry ability reflected in the results of the test can be caused by written tests in general can not be used effectively to assess students psychomotor skills, written tests can only assess the principles that accompany certain skills including
cognitive, affective, and psychomotoric skills [15]. The test used must have a high validity and reliability so as to provide valid and reliable measurement results. The inquiry ability will also form well if inquiry learning is experienced continuously by the students, can not be formed immediately in just one lesson. The application of free inquiry learning requires highly motivated learners, high academic ability, and willing to cooperate with their friends in building their knowledge. In addition, the faculty as a facilitator must also understand the nature of inquiry and develop its creativity in controlling inquiry-based learning.

3.2. Inquiry activity

The student inquiry activity is assessed using observation sheets and student worksheets. The observation sheet was used by the observer to mark students who showed spontaneous performance in spontaneous words, while the student worksheet was used to identify students' writing activities in writing. The result of the analysis on the overall activity of inquiry is shown in table 2.

**Table 2. Analysis of student inquiry activities.**

| Inquiry indicators                              | Students who are worked (%) | Categories |
|------------------------------------------------|----------------------------|------------|
| Responding to orientation questions from lecturers | 31                         | Low        |
| Formulate the problem                           | 72                         | High       |
| Make a hypothesis                               | 38                         | Average    |
| Collect data to test hypotheses                 | 48                         | Average    |
| Communicates findings                          | 62                         | Average    |
| Concluding                                      | 28                         | Low        |

Table 2 shows the activity of formulating the problem is highest (72%); while the average category for the activity hypothesized (38%), collected data to test the hypothesis (48%), communicated the findings (62%); and low category to respond to orientation questions from lecturers (31%) and concluded (28%). The average of inquiry activity is moderate (47%). The data in Table 2 shows a better performing ability compared to the data in Table 1 for most inquiry indicators except concluded (low category). These results indicate that lab work activities can not improve students' ability on concluded indicators. In contrast to other research results that simple physics lab work activities can improve the skills concluded on the Fluid Mechanics material [16].

Assessment of inquiry activities with observation sheets and student worksheets can assess students in detail throughout their learning so as to produce a more complete data. In this case a careful and skilled observer is required to observe student activities. In addition, student worksheets should be thoroughly examined to find inquiry statements written by students.

3.3. Lab work performance

Inquiry learning also includes hands-on activities such as lab work. Inquiry learning in the laboratory can provide learning experiences, develop scientific inquiry interests and abilities, increase understanding and ability to apply scientific concepts to learners [17]. In this study the performance of the lab work is assessed by using assessment rubric designed according to the stages of practicum of DNA isolation covering aspect of preparation of work, work plan, equipment usage, taking of material, participation in work, and ending activity. The results of the assessment can be seen in table 3.

**Table 3. Assessment of DNA Isolation lab work performance.**

| Value Interval | Students who are assessed (%) | Categories |
|----------------|-------------------------------|------------|
| 0-35           | 10                            | Low        |
| 36-71          | 0                             | Average    |
| 72-100         | 90                            | High       |
Table 3 illustrates that almost all students (90%) demonstrated excellent performance during DNA isolation lab work. As many as 3 people (10%) of students who are in low category because they are not present at the time of the lab so there is no score of its performance. Students look happy and excited at the time the practice takes place so that the value of its performance is high. In lab work activities, students can discuss before acting, cooperate or share tasks in doing work, observing the reactions and changes that occur in the sample, record the data and report the results of the lab. Students are given the freedom and responsibility to conduct experimental activities as well as a scientist working in the laboratory.

Based on these results can be stated that the rubric is the right instrument for use in assessing inquiry ability. Rubric is a detailed criteria to capture all the performance displayed by students in their lab work (task). Rubrics and tasks are the necessary instruments in the performance assessment. Using rubrics can improve scoring reliably but not facilitate valid decisions for performance assessment, potentially to improve learning because the rubric creates explicit expectations and criteria as well as facilitates feedback and self-assessment [18]. In another study [19] found that science teachers tend to use the formative assessment approach in assessing inquiry learning because it can assess the progress and innovation of students who are growing during learning.

4. Conclusion
Based on the study it can be concluded that free inquiry learning is not maximal in shaping the prospective biology teachers’ inquiry ability; low ability based on inquiry test results, inefficient ability of inquiry for aspect of inquiry activity and high ability to aspect of performance of lab work.

Suggestions can be given that the use of tests to assess the ability of inquiry for aspect of performance of students to aspect of performance of students to be reviewed again, while the observation sheet, student worksheets and rubrics can be used to assess the inquiry ability.

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