Effective Laboratory Work in Biochemistry Subject: Students' and Lecturers' Perspective in Indonesia

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Abstract

Biochemistry subject had problem in learning and teaching, especially in laboratory work. We explored laboratory learning implementation in Biochemistry subject. Participants of this research were 195 students who took biochemistry subject and 4 lecturers of biochemistry in three universities in Indonesia. We obtained data using questionnaires and free response data. Questionnaires students' analysis showed there were two statements that very positive perception, five statements that obtained positive perception and ten statements with negative perception. Biochemistry lecturers questionnaire analysis showed seven statements that had been implemented and nine statements had not been implemented. Free response data indicated that effective learning in the laboratory was affected by several aspects which were pre-lab stage that could increase the students' motivation, lab-work stage with complete tools and materials as well as better ability of the assistants, and post-lab stage that could give feedback to the experiments' report and chances for the students to present their investigation results.

Keywords: Biochemistry, Effective learning, Laboratory work

1. Introduction

1.1 Higher Education Curriculum in Indonesia

Starting in 1994 through the decree of the Minister of Education and Culture of the Republic of Indonesia No. 056/U/1994, the higher education curriculum prioritized the achievement of mastery of science and technology, referred to as Content Based Curriculum. Afterwards, in 2000, Indonesia reconstructed its' curriculum concept into Competency Based Curriculum in accordance with the UNESCO message through the four pillars of education concept, namely learning to know, learning to do, learning to be, and learning to live together.

However, the higher education condition in Indonesia had not been able to meet the demands of the qualifications of various occupations and professions in the global era. Demands as well as supports to develop the standards of the graduates' qualifications had prompted the issuance of Presidential Regulation of the Republic of Indonesia No. 8 of 2012 on Indonesian National Qualifications Framework (KKNI). The regulation stated that:

"*Indonesian National Qualifications Framework, hereinafter referred to as KKNI, was a competence qualification benchmarking framework that could compare, standardize, and integrate education field and job training field as well as work experience in order to commend one's competence in accordance with the job's structure in various sectors"*

KKNI was expected to be able to fulfill the achievement of the higher education mission in the 21st century.

1.2 Biochemistry Laboratory Work: Literature Review

Biochemistry was included in a science subject with applications in many fields such as medicine, agriculture, nutrition and industrial (Nelson & Cox, 2008: 2). In the universities in Indonesia, Biochemistry subject was offered to the students majoring in Chemistry study program. Some research reported that Biochemistry was one of the subjects that were difficult for students to understand (Varghese et al., 2012; Anwar et al., 2013; Broman et al. 2011). The abstract concept that required high thinking and the very limited time to deliver the materials had become the constraints on Biochemistry learning (Jidsejo et al., 2009; Varghese et al., 2012).

Biochemistry teaching and learning were not only done in the classroom, but in the laboratory as well. Laboratory work was expected to be able to provide experience for students about the correlation between the theories with the real world (Ottander&Greelson, 2006). The ability to analyze and to argue could also be obtained through experiments in the laboratory (Hofstein et al., 2008).

According to Domin (1999), laboratory-based learning was classified into four types, namely expository, inquiry, discovery and problem-based. This type of learning was distinguished by three descriptors, namely outcome, approach, and procedure (Table 1). Expository follows a deductive approach, predetermined outcome, and procedure is given to the students. This type is designed to facilitate the development of lower-order cognitive skills. Inquiry lessons are inductive, students generated their own procedure, and have an undetermined outcome. This method gives students the opportunity to improve their ability to engage in authentic investigative processes. Discovery is inductive, predetermined outcome and the procedure are given to the students. The problem of this method is time consuming. Problem based follow deductive approach, predetermined outcome and students generated their own procedure. Problem based learning requires students to think about they are doing and why they do it. Like discovery instruction, problem based is time consuming. Feyzioglu (2009) divided the laboratory application into three methods, namely semi-open-ended experiments, open-ended experiments, and hypothesis-based experiments.

Table 1. Descriptors of the laboratory instruction styles

No	Types	Outcome	Approach	Procedure
1.	Expository	Predetermined	Deductive	Provided
2.	Inquiry	Undetermined	Inductive	Student generated
3.	Discovery	Predetermined	Inductive	Provided
4.	Problem-based	Predetermined	Deductive	Student generated

In Indonesia, laboratory learning using the expository method was the most popular among others. Expository was a lecturer-centered learning method. Every phase of the working procedure in the laboratory was determined by the lecturer. The students were only following the instructions as stated in the laboratory work manual (Domin, 1999). According to Gallet (1998), the limitations of expository laboratory learning were: (i) The macroscale cookbook-formula experiments do not allow student initiative in the chemistry laboratory, (ii) A student can synthesize a compound without understanding the chemistry involved, (iii) There is no room for student hypothesis and errors; the standard procedure works as a recipe: one has to finish with the right cake, (iv) The student is not taught to assume his or her responsibility in a group: everyone does the same thing at the same time, and (v) When students work in pairs on the same setup, the lecturer has no means to identify which part of the student's report (or procedure) is an original creation.

Testing the learning effectiveness in the laboratory needed to be conducted as it was very important for training many skills such as chemistry skills, practical skills, etc (Reid & Shah, 2007). According to Pickering (1987), learning in the laboratory could build confidence, increase understanding, and was able to provide illustrations to students about scientific methods.

1.3 Effective Learning

Brown & Atkins (2002) explained that effective learning showcased the success of teaching that involved lecturers and students. It was in accordance with Allan et al. (2009) who emphasized that effective learning was based on the interaction between students and lecturers as partners in learning instead of knowledge transfer.

According to Brusoni et al. (2014),a perfect learning covered two things namely students' satisfaction and students' performance in the assessment. A good lecturer was a lecturer who could give support to the learning activities to achieve better learning outcomes (Biggs & Tang, 2011).

Effective learning definition could be seen from several perspectives. Abrami et al. (1997) showed the definition of effective learning in three perspectives. The first perspective was called the product definition, emphasizing on the students' positive changes. The second perspective was called the process definition, focusing on the instructors' activities before and after the learning. The third perspective was called the process-product definition, focusing on the combination that connected what the instructors did and how the students produced positive changes.

According to Reid & Shah (2007), laboratory work consisted of three stages, namely pre-lab exercise, laboratory time, and post-lab tasks. Effective learning in the laboratory happened if the three stages were well connected. If we referred to the effective learning perspective by Abrami et al. (1997), this research employed the process definition.

In the context of this research, we defined effective learning in the laboratory as the lecturers' quality in the pre-lab, laboratory time, and post-lab task activities, and the students' positive influence were in the form of behavior or response to the learning in the laboratory in Biochemistry subject.

1.4 Aims

This research aimed to identify the learning quality in the laboratory in Biochemistry subject. The research questions covered:

1) What did the students and the lecturers involved in the learning in the laboratory do in Biochemistry subject?
2) How was the learning effectiveness in the laboratory based on the students' perspectives in Biochemistry subject?
3) How was the learning effectiveness in the laboratory based on the lecturers' perspectives in Biochemistry subject?

We were certain that the identification of the laboratory learning implementation in Biochemistry subject needed to be conducted to (i) design an effective learning model in the laboratory in Biochemistry subject, and (ii) improve the role of lecturers and teaching assistants in the implementation of learning in the laboratory.

2. Method

2.1 Participants

Participants of this research were (i) fifth semester students batch 2014/2015 who took Biochemistry subject in three universities in Indonesia, and (ii) lecturers of Biochemistry subject in the three universities. Variety samples based on the demographic factor were shown in Table 2. All the students followed the laboratory instruction in these four topics, namely carbohydrate identification, protein identification, enzymes and fat identification.

Table 2. Summary of Sample Demographics (N=195)

Sample	Background	Sub Total	
		n	%
Student	*Gender*		
	Male	61	31
	Female	134	69
	College Location		
	Yogyakarta	90	46
	Mataram	105	54
Lecturer	*Gender*		
	Male	1	25
	Female	3	75
	Level of Education		
	Master	3	75
	Doctor	1	25

2.2 Instruments

The instruments used were questionnaires for the students and the lecturers of Biochemistry subject. There were six indicators in the questionnaires for the students. They were:

1) Lab performance in Biochemistry classes.
2) Lecturers' involved in laboratory work implementation.
3) Laboratory works relevance with the students' needs.
4) Integration of laboratory work in class learning.
5) Implementation of laboratory work as an effort to train critical thinking skills.
6) Reciprocal adherence between lab performance and the students' thinking ability.

Questionnaires contained demographic data, Likert statements and students' free responses related to the laboratory work implementation. Demographic data consisted of sex and the location of the university. Likert statements

consisted of seventeen statements with four Likert scales (never/sometimes/often/very often). Students' free responses asked the students to provide response to the implementation of effective laboratory work according to the students.

Questionnaires for the lecturers of Biochemistry subject had six indicators. They were:

1) Lab performance in Biochemistry classes.
2) Lecturers' involved in laboratory work implementation.
3) Students' involvement in laboratory work implementation.
4) Integration of laboratory work in class learning.
5) Implementation of laboratory work as an effort to train critical thinking skills
6) Reciprocal adherence between lab performance and the students' thinking ability

As in the students' questionnaires, the lecturers' questionnaires also contained demographic data, Likert statements and lecturers' free responses related to the laboratory work implementation. Demographic data consisted of sex, last degree, and occupation status. Likert statements consisted of sixteen statements with four Likert scales (had never been implemented/had been discussed/had been planned to be implemented/had been implemented). Lecturers' free responses consisted of suggestions on the improvement of laboratory work implementation.

2.3 Data Analysis

Validity of the questionnaires was tested by four experts in chemistry education from two universities in Indonesia. Valid questionnaires were distributed to the students and lecturers of Biochemistry subject at the same time after all the topics in the laboratory work were completed. The average of each statement was calculated and converted to find out the students' perception: very positive, positive, negative, very negative (Table 3).

The lecturers' questionnaire analysis was conducted by calculating the average of each statement. After each statement was tested, the lecturers' and the students' responses were collected to figure out the learning quality in the laboratory from the students' and lecturers' perception.

Table 3. Categorical Perception (Djemari, 2008)

No	Calculation of Each Statement	Categorical Perception
1.	$X \geq \overline{X} + SD$	Very Positive
2.	$\overline{X} + SD > X \geq \overline{X}$	Positive
3.	$\overline{X} > X \geq \overline{X} - SD$	Negative
4.	$X < \overline{X} - SD$	Very Negative

X = average each statement

$\overline{X}$ = average score

SD = standard deviation

3. Results

3.1 Questionnaire Analysis

Questionnaires distributed to the students showed a different average for each statement (Table 4). The average of each statement was converted to see the students' perception of the laboratory learning in Biochemistry subject.

Table 4. Students' Perception on the Laboratory Learning in Biochemistry Subject

No.	Statements	Rating[a]		Categorical Perception
		Mean[b]	SD	
1.	I work well in groups during the biochemistry laboratory work.	3,16	0,63	Very positive
2.	Through the biochemistry laboratory work, I have a great opportunity to develop my interest in biochemistry topics.	2,8	0,7	Very positive
3.	The biochemistry, materials being practiced are consistent with the materials being taught in the class.	2,66	1,05	Positive
4.	The laboratory work instruction is easy to understand, and guides the implementation of the experiment clearly.	2,3	0,86	Positive
5.	I feel comfortable working in the laboratory.	2,18	0,85	Positive
6.	The laboratory equipments in the biochemistry laboratory work are complete.	1,96	0,75	Positive
7.	The biochemistry laboratory work starts with a problem to be solved in groups during the experiment.	1,45	0,63	Negative
8.	Before work in the laboratory, I am given an opportunity to conduct a preliminary study to prepare for the experiment.	1,5	0,7	Negative
9.	Before work in the laboratory, I am given an opportunity to design an experiment to solve the problem given by the lecturer.	1,29	0,52	Negative
10.	The lecturer gives a short explanation on the topic to be practiced.	1,56	0,68	Negative
11.	The lecturer gives feedback after the laboratory work is over.	1,31	0,51	Negative
12.	The lecturer gives an opportunity to discuss the results of the experiment during the laboratory work.	1,29	0,51	Negative
13.	Lecturer relates the results of the biochemistry laboratory work with the concepts the students have learned in the class.	1,31	0,46	Negative
14.	The lecturers evaluate the laboratory work and the explanation of the theories in the class holistically.	1,36	0,5	Negative
15.	The biochemistry laboratory work is implemented by making use of the potentials from the surrounding environment.	1,69	0,71	Negative
16.	The discussion of the laboratory work results is done not only in the laboratory.	1,73	0,77	Negative
17.	In my opinion, the laboratory work is useful for my future life.	2,22	0,76	Positive

[a]Scale for ranking: 1.00, never; 2.00, sometimes; 3.00, often; 4.00, very often

[b]N = 195

Research results showed that there were two statements that showed a very positive perception by the students. Those statements were "I work well in groups during the laboratory work", and "Through laboratory work, I have a great opportunity to develop my interest in Biochemistry topics".

There were five statements that obtained positive perception from the students. Those statements were "The biochemistry, materials being practiced are consistent with the materials being taught in the class", "The laboratory work instruction is easy to understand, and guides the implementation of the experiment clearly", "I feel comfortable working in the laboratory", "The laboratory equipments in the biochemistry laboratory work are complete", and "In my opinion, the laboratory work is useful for my future life". There were eleven statements with low average that showed the negative perception of the students. Those statements were "The biochemistry laboratory work is started with a problem to be solved in groups during the experiment", "Before work in laboratory, i am given an opportunity to conduct a preliminary study to prepare for the experiment", "Before work in laboratory, i am given an opportunity to design an experiment to solve the problem given by the lecturer", "Lecturer gives a short explanation on the topic to be practiced", "Lecturer gives feedback after the laboratory work is over", "Lecturer gives an opportunity to

discuss the results of the experiment during the laboratory work", "Lecturer relates the results of the biochemistry laboratory work with the concepts the students have learned in the class", "The lecturers evaluate the laboratory work and the explanation of theories in the class holistically", "The biochemistry laboratory work is implemented by making use of the potentials from the surrounding environment", and "The discussion of the laboratory work results is done not only in the laboratory".

Biochemistry lecturers' questionnaire analysis showed seven statements that had been implemented (very positive perception) on the laboratory learning in Biochemistry subject (Table 5).

Table 5. Lecturers' Perception on the Laboratory Learning in Biochemistry Subject

No.	Statements	Rating[a]		Lecturers' Perception
		Mean[b]	SD	
1.	The biochemistry lecture is equipped with laboratory work activities.	3,5	0,6	Very Positive
2.	The goals of the laboratory work are explained clearly in the laboratory work manual.	3,75	0,5	Very Positive
3.	The implementation of laboratory work is integrated with the theoretical learning in the class.	3,75	0,5	Very Positive
4.	The materials being practiced are consistent with the materials students learning in the class.	3,75	0,5	Very Positive
5.	Before the implementation of the laboratory work, lecturers explain the goals of each laboratory work topic.	3,5	0,58	Very Positive
6.	Before the laboratory work is implemented, students are given opportunities to conduct a preliminary study (ranging from a library research to laboratory work design) to prepare the implementation of the laboratory work.	1	0	Very Negative
7.	Before the laboratory work, students are given opportunities to discuss anything related to the preliminary studies they have conducted.	1	0	Very Negative
8.	During the laboratory work, students are given freedom to conduct an experiment according to the results of their preliminary study.	1	0	Very Negative
9.	After the laboratory work, students are given opportunities to present orally the results of their experiments.	1	0	Very Negative
10.	Students discuss the results of their experiments in the class.	1,25	0,5	Negative
11.	As a part of the implementation of laboratory work, students use the cases prevailing in the society.	1,25	0,5	Negative
12.	The laboratory work makes use of the environmental potentials around the laboratory.	1,75	0,5	Negative
13.	Lecturers evaluate the integration of laboratory work and theories.	3,5	0,58	Very Positive
14.	Lecturers give feedback on the students' written laboratory work reports.	1,5	0,58	Negative
15.	Laboratory work instruction is designed to exercise students' critical thinking skill.	1,25	0,5	Negative
16.	The laboratory work instruction is reviewed and revised every year.	4	0	Very Postive

[a]Scale for ranking: 1.00, had never been implemented; 2.00, had been discussed; 3.00, had been planned to be implemented; 4.00, had been implemented

[b]N = 4

Those statements were "The biochemistry lecture is equipped with laboratory work activities", "The goals of the laboratory work is explained clearly in the laboratory work manual", "The implementation of laboratory work is integrated with the theoretical learning in the class", "The materials being practiced are consistent with the materials students learn in the class","Before the implementation of the laboratory work, lecturers explain the goals of each laboratory work topic", "Lecturers evaluate the integration of laboratory work and theories", and "The laboratory work instruction is reviewed and revised every year".

Statement that showed aspects that had not been implemented and had been discussed were "Before the laboratory work is implemented, students are given opportunities to conduct a preliminary study (ranging from a library research to laboratory work design) to prepare the implementation of the laboratory work", "Before the laboratory work, students are given opportunities to discuss anything related to the preliminary studies they have conducted", "During the laboratory work, students are given freedom to conduct an experiment according to the results of their preliminary study", "After the laboratory work, students are given opportunities to present orally the results of their experiments", "Students discuss the results of their experiments in the class", "As a part of the implementation of laboratory work, students use the cases prevailing in the society", "The laboratory work makes use of the environmental potentials around the laboratory", "Lecturers give feedback on the students' written laboratory work reports", and "Laboratory work instruction is designed to exercise students' critical thinking skill".

3.2 Free Response Data

In describing the effectiveness of learning in the laboratory in Biochemistry subject, students gave comments and suggestions freely. Suggestions and comments given were categorized into three areas which were (i) pre-laboratory stage, (ii) laboratory work, and (iii) post laboratory stage.

3.2.1 Theme (i) pre-laboratory Stage

Students gave comments on the pre-laboratory stage in two areas, namely (i) initial response phase and (ii) teaching assistant performance. First, according to the students, the initial response phase did not give them many benefits because they were only given irrelevant questions from the laboratory work subjects. The example of the statement was "The questions in the initial response phase were not beneficial for the laboratory work of each topic".

Some students also gave suggestions indicating that the pre-laboratory stage was supposed to be conducted by giving motivation and explanation on the importance of the laboratory work implementation for each of the topics.

Second, students also suggested to improve the performance of the teaching assistants. They suggested the teaching assistants to be more discipline, to master the laboratory work topics and the concepts of each topic so that in the beginning of the laboratory work, the teaching assistants could give clear explanations, and be more friendly to the students. In addition, the students also suggested to increase the lecturers' involvement in the pre-laboratory process.

3.2.2 Theme (ii) Laboratory Work Stage

Students gave suggestions on the laboratory work stage in three areas, namely (i) completeness of the tools and materials for the laboratory, (ii) Biochemistry subject lecturers' involvement, and (iii) the teaching assistant's ability in explaining and demonstrating the laboratory instructions.

The first area focused on the tools and materials completeness of each laboratory work topics. The students' statement was "The teaching assistants should prepare the needed tools and materials listed on the laboratory instructions". Statements of some other students were:

> "Teaching assistants were supposed to be able to operate all tools that were used in each topic written in the laboratory instructions"
>
> "The written materials in the laboratory instructions were supposed to be prepared carefully for an effective laboratory work"

Second, the involvement of the Biochemistry subject lecturers should be increased. The students suggested that the presence of the lecturers was needed in every implementation of laboratory work. Their statement was "The presence of the lecturers could help us to understand the laboratory instructions".

Third, students commented on the importance of increasing the teaching assistants' ability in demonstrating the laboratory instructions. Some students stated "Good teaching assistants would be able to master the laboratory instructions". One student said that "Good teaching assistants would care with the difficulties that we encountered".

3.2.3 Theme (iii) Post Laboratory Stage

Learning effectiveness in the laboratory in Biochemistry subject was also affected by post laboratory stage. The focus of this stage was the laboratory work report writing. Some students suggested that "The feedback on report writing was not supposed to be only limited to the assessment, but to the suggestions to improve the report as well". A student stated that "Learning in the laboratory would be effective if we were given opportunity to present the results of our investigation".

The responses from four lecturers of Biochemistry subject focused on three areas which were the improvement of teaching assistants' quality, improvement of the laboratory facilities, and up to date laboratory work topics. One lecturer suggested that "Laboratory learning would be effective if the teaching assistants were qualified. Therefore, assistants' training was compulsory for every learning topic in the laboratory". Two lecturers stated that "Laboratory learning would be effective if the tools and material support were provided completely". One lecturer suggested "There needed to be a cooperation of the teaching team to determine up to date learning topics in the laboratory with the students' needs so that the learning effectiveness in the laboratory could be achieved".

4. Discussion

The students' and lecturers' questionnaire results indicated that the laboratory work in Biochemistry subject was using the expository method or commonly known as cookbook laboratory. This method repeated the instructions given with pre-determined results from the instructors (Domin, 1999). The planning and designing experiments stages were eliminated with this method (Copriady, 2015).

Ault (2002) indicated that there was nothing wrong with cookbook laboratory. Recipes and procedures were important parts of the laboratory work that could develop many skills (Ault, 2002). Sigler and Saam (2007) argued that cookbook laboratory was a good method if it was used to deliver basic knowledge.

In contrary to Ault's (2002) opinion, some research had reported the weaknesses of cookbook laboratory in the learning process. Reid & Shah (2007) argued that cookbook did not give an opportunity to students to develop many skills. Cookbook only emphasized on how the data were gathered so that students only thought about how to collect the data instead of training themselves to identify and to control the variables (Monteyne&Cracolice, 2004). It was recommended to use other methods such as inquiry and problem-based. Both methods were reported to have an advantage to be implemented in the laboratory learning in universities. Inquiry and problem-based laboratory learning was reported to be able to increase the students' ability in thinking skills and practical skills (Cacciatore&Sevian, 2009; Fakayode, 2014; Hakim, 2016).

According to Carnduff dan Reid (2003), laboratory work in universities was needed to train three areas which were practical skills, transferable skills, and intellectual stimulation. These skills could be trained by giving opportunities to students to design their experiments in the laboratory which were integrated into the learning process (Limoto& Frederick, 2011; Tsaparlis&Gorezi, 2007).

Based on the students' perception, the laboratory learning in Biochemistry subject was not effective in the pre-lab, lab work and post lab stages. According to Reid & Shah (2007), pre-lab was a short experience given to students to start learning in the laboratory. Pre-lab stage could stimulate and train students to plan the implementation of laboratory work. In addition, pre-lab was very essential to control the experiments selections that were safe for the students (Jean Burnham, 2013).

Lab-work stage needed better teaching assistants' performance. Herrington &Nakhleh (2003) suggested the teaching assistants' quality improvement in three aspects namely knowledge, communication ability, and affective domain. Therefore, there should be sufficient trainings for the teaching assistants. The faculty also needed to give support in the form of laboratory facilities improvement, staff and teaching assistants' capacity building (Bruck& Towns, 2009).

The post - lab stage could be in the form of simple assessment of what had happened during the experiment stage in the laboratory (Reid & Shah, 2007). In general, this stage would give assignments to students to write reports on the produced experiments results. However, the students' perceptions indicated that the experiments' report would be effective if the lecturers and the teaching assistants gave responses or feedback to their writing. There were many benefits that students could get from writing the experiments report. The writing experiments report could be used to measure the students' critical thinking ability (Hoyo, 2003; Contakes, 2016). In addition, through the report writing, students could build arguments that were positively correlated to the oral communication ability (Walker & Sampson, 2013).Duzor (2016) reported that report writing could connect the theories and practices in the laboratory.

The questionnaire analysis results indicated that the learning in the laboratory in Biochemistry subject was still

cookbook in nature and had not yet designed to train the students' thinking skills. Students' and lecturers' perception argued that effective learning in the laboratory was affected by several aspects which were pre-lab stage that could increase the students' motivation, lab-work stage with complete tools and materials as well as better ability of the assistants, and post-lab stage that could give feedback to the experiments' report and chances for the students to present their investigation results.

It was recommended that learning improvement in the laboratory needed to be conducted to achieve the learning objectives in accordance with the KKNI. Improvement of tools and materials, facilities for laboratory learning, technique, preparation and evaluation tools to produce an effective learning were also needed. In addition, trainings for the assistants were also needed to be done so that they would be able to help the lecturers to guide the learning activities in the laboratory.

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