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The exploration of biochemistry laboratory activity: Study on higher education in Mataram

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Abstract: As the core of science learning, laboratory work is inseparable from learning chemistry, including biochemistry. However, the implementation of laboratory work needs reconstruction, especially in higher education, so an initial study is needed to understand the problems in laboratory work at universities. This article was a study of the working conditions of the biochemistry laboratory at the University of Mataram. This study included quantitative research with students (N = 250), lab work assistants (N = 36), laboratorium staff (N = 4), and biochemistry lecturers (N = 4) as respondents. Techniques for obtaining data through participatory observation and questionnaires. Supporting data were obtained through interviews with students, lecturers, laboratory assistants, and laboratory personnel representatives. The results showed that the implementation of biochemistry lab work at the University in Mataram had gone through the pre-laboratory, laboratory work, and post-laboratory stages. Expository, inquiry, and demonstration are lab work methods, with 80% of the implementation using the expository method. Instructions related to waste handling have not been carried out in the implementation of biochemistry lab work. Based on these findings, several recommendations were put forward for improving the biochemistry lab work at the University.

***Keywords**: biochemistry, higher education, laboratory work, pre-lab, post-lab*

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INTRODUCTION

Lab work is a learning activity at the core of science learning, including biochemistry. Experts argue that integrating students with laboratory activities provides many benefits (Hodson, 1998). Specific outcomes from laboratory activities include developing inquiry and technical skills, increasing motivation, and getting students accustomed to analyzing problems (Gaddis & Schoffstall, 2007). Students can also develop a deeper understanding of concepts and practice their ability to explain both verbally and in writing (King et al., 2017; Rootman-le Grange & Retief, 2018).

Biochemistry is a compulsory subject in the chemistry curriculum at the University. These courses have carried out lab work in the learning process to cover the taught topics. For example, the discussion of protein has involved qualitative and quantitative analysis of protein techniques. Measurement of protease activity is also a lab work lesson in understanding the subject of enzymes. Lab work can be considered an important part of biochemistry learning (Anwar et al., 2017).

The higher education curriculum in Indonesia demands continuous learning innovation, including the chemistry curriculum. Learning outcomes include 4 elements: attitudes, general skills, special skills, and knowledge. This achievement must be connected to the needs and assessed by users or stakeholders (Direktorat Jenderal Pembelajaran dan Kemahasiswaan, 2016).

Laboratory work in universities requires the implementation of 3 important stages, namely the pre-lab, lab work, and post-lab stages. The three stages are ideally integrated with classroom learning so that students can relate the theory learned to the results of the observations obtained. If you want to provide many opportunities for students to conduct investigations, the planning stage is carried out before the pre-lab stage (Reid & Shah, 2007).

The pre-lab stage is where students study topics used in lab work (Reid & Shah, 2007). This stage can assist students in preparing for the implementation of lab work to prevent the possibility of failure. Pre-lab activities can be done individually or in groups (JeanBurnham, 2013; Kelly & Finlayson, 2007). Pre-lab activities can be carried out in 3 ways: pre-laboratory lectures, pre-laboratory quizzes, and pre-laboratory discussions (Agustian & Seery, 2017).

The lab work stage is the implementation of investigations in the laboratory according to the preparations made at the pre-lab stage. This stage is the core of the implementation of lab work, so it requires many skills, including skills using instruments, carrying out procedures that have been prepared at the pre-lab stage, making observations, recording investigative data, analyzing data, and interpreting investigative data (Reid & Shah, 2007). The success of the lab work stage is influenced by good pre-lab activities so that it can reduce the failure of investigations (Hensiek et al., 2016).

The post-lab stage is a review activity to strengthen and evaluate theoretical evidence from the investigation results (Reid & Shah, 2007). The post-lab stage can be carried out by discussing the relationship between content and the results of the investigation, making written reports and presentations of the result of the investigation, and providing feedback on the investigation process that has been carried out (Contakes, 2016; JeanBurnham, 2013; Walker & Sampson, 2013).

Laboratory work in higher education should reduce traditional methods that are more illustrative or demonstrative (Reid & Shah, 2007; Sigler & Saam, 2007; Tafa, 2012). Using Problem-Based Learning and inquiry methods provides more opportunities for students to practice many skills in carrying out laboratory work (Cacciatore & Sevian, 2009; Kelly & Finlayson, 2007; Winkelmann et al., 2015). Project giving can also be trained to develop student communication skills (McDonnell et al., 2007; Rootman-le Grange & Retief, 2018; Stout, 2016).

In recent years, green chemistry laboratory work has been initiated. The principle of reducing waste in the laboratory in the implementation of laboratory work at the University is important to be implemented to preserve the environment (Goh, 2020; Mammino, 2019). Green chemistry laboratory work has many advantages, including a safer laboratory for the environment, reducing university expenses related to purchasing materials, and being able to teach students environmentally friendly concepts when entering the world of work, especially in the chemical industry (Amstrong et al., 2018; Lasker et al., 2017; Timmer et al., 2018).

Initial studies are needed to understand problems in implementing laboratory work at the University (Tafa, 2012). The initial study's results will play a role in examining the stages that need to be improved to produce better laboratory work at the University level (Martin et al., 2011). This study aims to describe the working conditions of the biochemistry laboratory at the University of Mataram. It is hoped that the results of this research can benefit institutions to improve learning, especially in biochemistry.

METHODS

Procedure

This research includes quantitative research to examine the implementation of biochemistry lab work carried out so far. The techniques used in this study to obtain data were participatory observation and questionnaires. Supporting data were obtained through interviews with students, lecturers, laboratory assistants, and laboratory personnel representatives. This technique can help researchers assess the working conditions of the biochemistry lab in more depth (Best & Khan, 1999; Tafa, 2012).

In participatory observation, researchers observe what people do, listen to what is said, and participate in their activities (Marshall, 1995). In this study, researchers observed the implementation of all lab work events from 2017-2020 using the observation checklist assisted by 3 observers who had previously been trained using observation instruments. The parts observed were related to pre-lab activities, lab work, post-lab, student activities, and lab work assistants.

The type of interview used is a semi-structured interview, where the implementation is freer when compared to structured interviews (Esterberg, 2002; Stainback, 1988). The interview aims to find problems in a more open manner where the interviewee is asked for their opinions and ideas (Esterberg, 2002).

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Participants

This research was conducted at Mataram University in West Nusa Tenggara, Indonesia. The research samples were students of the chemistry education study program who took Biochemistry courses (N = 250), lab work assistants (N = 36), laboratorium staff (N = 4), and biochemistry lecturers (N = 4) at the University in Mataram (Table 1). Observations were made for 3 consecutive years, starting from 2017-2020, on implementing biochemistry laboratory work. The aspects studied are related to the implementation of lab work according to literature studies, namely pre-lab, lab work, and post-lab activities, lab work methods, the role of lab work assistants, and the handling of lab waste. Sample demography is presented in Table 1.

Table 1. Summary of Sample Demographics

Sample	Background	Sub-Total	
		n	%
Student	Gender		
	Man	75	30
	Women	175	70
Lab Assistant	Gender		
	Man	0	0
	Women	36	100
Laboratory Staff	Gender		
	Man	4	100
	Women	0	0
	Level of education		
	S1	3	75
	S2	1	25
	Employee Status		
	Civil servants	1	25
	Non-Civil Servants	3	75
Lecturer	Gender		
	Man	1	25
	Women	3	75
	Level of education		
	S2	2	50
	S3	2	50
	Employee Status		
	Civil servants	3	75
	Non-Civil Servants	1	25

Instruments

The instrument used for participant observation is a checklist of observations on pre-lab, lab work, and post-lab activities. Observers fill in the rubric according to the participants' pre-lab, lab work, and post-lab activities. The questionnaire compiled in this study was used to obtain information about the implementation of lab work from students and lab work assistants. A total of 3 indicators were used in the preparation of student questionnaires and lab work assistants, namely (1) the implementation of lab work in biochemistry learning, (2) the involvement of lecturers in carrying out biochemistry lab work, and (3) the role of lab work assistants in carrying out biochemistry lab work. The three indicators are developed into 5-6 statements with 4 answer choices: never, sometimes, often, and very often. The questionnaire that had been compiled was assessed by 3 experts in the field of chemistry education. The assessment instrument by the expert was arranged in the category of assessment, namely very poor (1), poor (2), moderate (3), good (4), and very good (5). The assessment instrument by the expert is equipped with comments and input (Aiken, 1985; Retnawati, 2016).

Data analysis technique

The results of observations of participants were tabulated in the form of descriptions through meetings with all observers. Questionnaire analysis was carried out by calculating the percentage of responses to each statement contained in the instrument. The results of the analysis of observations and

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questionnaires are summarized and used as the basis for compiling a list of questions for interview activities to support the study results.

RESULT AND DISCUSSION

Analysis of the Implementation of Biochemistry Laboratory Work

The implementation of laboratory work in the biochemistry course occurred in three stages, as shown in Figure 1. Each step had problems that were observed during this research.

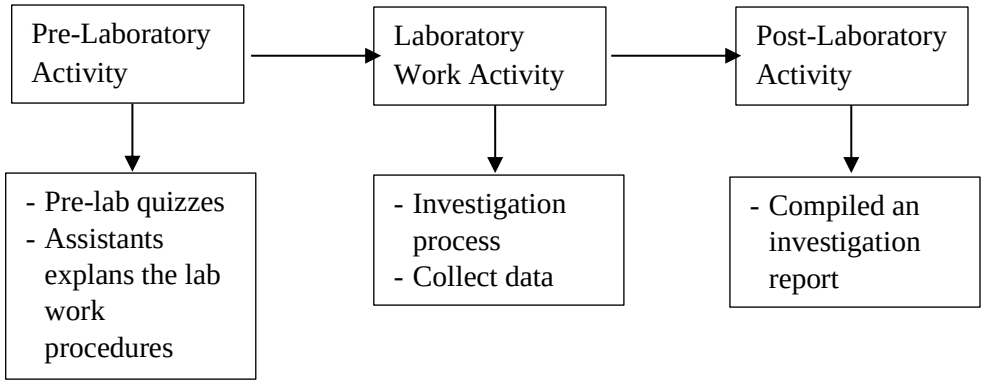

Figure 1. Activity Laboratory Work in Mataram

Participatory observation is carried out from the initial lab work session until the lab work session ends. Lab work is carried out in groups with 5-6 members in one group. Lab work assistants carry out the division of group members. The observations showed that students did pre-laboratory activities in the form of pre-lab quizzes; The form of questions is an essay composed by a lab work assistant with a total of 4-5 questions. The time for the problem is 5-10 minutes. After the pre-lab quizzes, the assistant explains the lab work procedures the student must complete. The investigation is carried out after the assistant has finished providing explanations.

Observations in the investigation process show that the preparation of tools and materials has been carried out by assistants assisted by laboratory staff. Tools and materials are placed in a place that makes it easy for students to pick them up as needed. In the investigation process, it was seen that students asked for more assistants when following work procedures even though the work stages had been explained previously. Several groups were seen working well with their group members. However, some groups appear to be dominated by only 1-2 members. This can be seen in every implementation of laboratory work.

During the implementation of lab work, several important things become student habits, namely mistakes in taking the right amount of material. This causes the ingredients that have been prepared are often insufficient. Observations of the investigation results have been done quite well, but the students have not done the temporary interpretation after the observation.

The post-lab activity observed was that students compiled an investigation report and collected it with the lab work assistant. Report processing is carried out for 1 week in the format specified by the lecturer. The lab work assistant performs the report assessment and value recapitulation before being submitted to the biochemistry lecturer. No feedback is given to students regarding the reports they have compiled.

Three lab work assistants accompany students for each meeting so that 1 assistant helps 2 groups carry out lab work. Observations of the lab work assistant based on the observation sheet show that 1) Assistants always assist students in carrying out lab work; 2) Some assistants do not masterwork procedures and often ask other assistants or laboratory assistants; 3) The assistant provides an assessment of the pre-lab quizzes and skills demonstrated by students; 4) The assistant has not helped students in interpreting the results of the observations; 5) The assistant has reminded students about work safety; and 6) The assistant has not reminded the students regarding the disposal of waste generated after lab work. Meanwhile, the observations of waste handling indicate that: 1) Biochemistry lecturers do not handle chemical waste during lab work. This is because the lecturer does not follow the

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implementation of lab work until it is finished; 2) Assistants assist laboratory staff in handling chemical waste during biochemistry lab work; 3) Students do not get supervision from assistants in handling chemical waste. Several students were seen throwing the remaining reagents into the trash, and 4) Students were not briefed on handling chemical waste during biochemistry lab work.

Questionnaire Analysis

The analysis of the questionnaire given to students showed a positive response to the implementation of biochemistry lab work. The percentage of student responses to frequent and very frequent choices on the implementation of laboratory work is shown in a statement that describes their interest and comfort in doing biochemistry lab work, tools and materials that are always available in the laboratory when doing biochemistry lab work, and their enthusiasm for studying biochemistry lab work materials as seen in Table 2.

Table 2. Student Responses to the Implementation of Biochemistry Lab Work

No.	Statement	Response (%)			
		Never	Sometimes	Often	V often
1.	Lab work is fun for me.	0	13.2	52.4	34.4
2.	Lab work allowed me to develop an interest in biochemistry	0	8	55.6	36.4
3.	Lab work material follows the material taught in class	2.8	20.8	61.2	15.2
4.	I feel comfortable doing investigations in the laboratory	0	13.6	57.2	29.2
5.	Lab work equipment is always available in the laboratory	0	27.6	58.8	13.6
6.	Lab work materials are always available in the laboratory	0	26	61.2	12.8
7.	The lecturer explains the lab work material	9.2	60.4	23.2	7.2
8.	The lecturer discusses the results of the investigation after the lab work process	40	58	0	2
9.	The lecturer connects the results of the investigation with the concepts learned in class	48	40.4	5.2	6.4
10.	Lab work assistants assist if we experience difficulties	30	36	34	0
11.	The lab work assistant gives a fair assessment	0.4	12.4	64.8	22.4
12.	Lab work assistants master lab work material	52.4	43.2	2.4	2
13.	Lab work assistants are skilled in using tools in the laboratory	40	52	8	0
14.	Before carrying out lab work, I studied the topic of the investigation to be carried out	0	11.6	62.4	26
15.	The lab work manual clearly outlines the investigation procedure that must be carried out	24.8	38	15.2	22
16.	Lecturers provide feedback on the investigation reports that I have compiled	66.8	22.4	10.8	0

Negative responses are also shown in several statements, among which the lecturer sometimes provides material before lab work and discusses the results of investigations, the vagueness of laboratory manual work and mastery of the material, and the use of laboratory tools by assistants. The highest negative response is shown by statements related to lecturer feedback on the investigation reports prepared by students.

Complaints regarding the implementation of lab work on the questionnaire show that students are happy and interested in carrying out lab work but have difficulty making investigation reports. They feel that too many reports are prepared and never get feedback from the lecturer or assistant. In addition, they find it difficult to understand manual laboratory work, so failure to collect data cannot be

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avoided. Some students gave suggestions for giving feedback on the reports they compiled and the opportunity to convey the results of their investigations in classroom learning.

Analysis of the questionnaire given to the assistant showed a positive response to several statements (Table 3). The assistant thinks that there are no obstacles in coordinating with lecturers before or during the implementation of biochemistry lab work; lecturers can always be contacted and coordinate in the implementation of lab work; lab tools and materials are always available; laboratory assistants assist them in preparing the implementation of lab work; and the lecturers have prepared report assessment instruments and practical skills.

Table 3. Assistant Responses to the Implementation of Biochemistry Lab Work

No.	Statement	Responses (%)			
		Never	Sometimes	Often	V often
1.	I coordinate with the biochemistry lecturer before the lab work begins	0	0	27.78	72.22
2.	I master all stages of work in each laboratory lesson	0	22.22	33.33	44.45
3.	Being an assistant is a fun activity for me	0	33.33	66.67	0
4.	Laboratory assistants assist us in preparing for the implementation of lab work	0	41.67	58.33	0
5.	Investigation tools are available when we are assistants	0	0	77.78	22.22
6.	Materials for investigation are available while we are assistants	0	0	69.44	30.56
7.	Other assistants and I coordinate with biochemistry lecturers during lab work	0	0	69.44	30.56
8.	Biochemistry lecturers monitor the implementation of lab work	0	0	75	25
9.	We can contact biochemistry lecturers if they have difficulties	0	0	55.56	44.44
10.	I assess students' practical skills during the implementation of lab work	0	0	66.67	33.33
11.	I have instruments to assess practical skills	0	0	30.56	69.44
12.	The lecturer gave me an instrument for assessing student's practical skills	0	0	30.56	69.44
13.	I provide feedback on reports prepared by students	77.78	22.22	0	0
14.	I have an instrument for assessing student inquiry reports	0	0	80.56	19.44
15.	Judging student investigation reports is an unpleasant thing for me	0	52.78	47.22	0
16.	The lecturer gave me a student investigation report assessment instrument	0	0	63.89	36.11

Negative responses were given regarding the clarity of manual lab work; sometimes, being an assistant is unpleasant, and giving feedback on student reports and assessing student reports is unpleasant. Free response data shows that assistants often have difficulty helping students carry out biochemistry lab work, especially in assessing investigation reports. In addition, being an assistant often takes up much of their time, especially when assessing investigative reports.

Interview Analysis

The results of the interviews were conducted to strengthen the findings in the observation and questionnaire analysis. Interviews were conducted with lecturers, laboratory staff, assistants, and students. The information obtained from the lecturer shows that the delivery of the material follows the syllabus, but the explanation of the topic to be investigated in the laboratory is not done at first face to

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face in class. According to several lecturers, the lab work manual has clearly described the topics to be investigated. Feedback on student investigation reports is never given because the lecturer trusted the assistant to evaluate the report. The lecturer also said he rarely participated in lab work until the end because it coincided with other activities. Other information shows that the coordination between lecturers and assistants is only in the form of schedules and techniques for lab work, while investigation material is not submitted to the assistant. The information given by the lecturer shows that expository lab work is a method that has been used in the implementation of biochemistry lab work.

Interviews with laboratory staff revealed that assistants and laboratory staff prepared materials and tools for investigations in the laboratory. Reagents are prepared several hours before the implementation of lab work as well as the tools needed. The materials prepared by the assistant are often deficient, so each meeting often returns reagents. According to the laboratory staff, this is due to the lack of students' ability to calculate the amount of reagent used, so repetition due to mistakes is often made. This causes the amount of chemicals consumed to be more than expected. According to laboratory staff, waste treatment has not been carried out meaningfully. The disposal of the remaining reagent is usually done after being diluted, but students seem to pay less attention to handling the waste from the lab work. There are still students who throw waste in the trash.

Assistants expressed their difficulty in evaluating student investigation reports. They argue that students are less able to explain the results of the investigation well. The discussion has not yet connected the results of observations and supporting theories. In addition, the assistant felt that the evaluation of the report took a long time, which made it unpleasant. Students also thought that it would be better if they were allowed to present their observations during class.

Discussion

Lab work in Mataram based on document analysis shows that 80% use the expository method, 10% use demonstrations, and 10% use inquiry guides. Reid & Shah (2007) state that university lab work should be designed to stimulate student skills and attitudes. As a widely used method, the Expository is incapable of practicing this and can only be used as knowledge recognition (Monteyne & Cranolice, 2004; Sigler & Saam, 2007). Lab work should provide many opportunities for students to develop investigations and communicate the results of investigations so that thinking skills, practical skills, communication skills, and attitudes can be properly trained (Limoto & Frederick, 2011; Quitadamo & Kurtz, 2007; Tsaparlis & Gorezi, 2007; Walker & Sampson, 2013).

One method that gives students many opportunities to develop an investigative process in biochemistry lab work is inquiry. Rens et al. (2009) revealed that inquiry allows students to participate more in the investigation process. This is certainly more effective in increasing understanding, training communication skills, increasing problem-solving skills, and increasing motivation so that it is suitable for application in higher education (Conway, 2014; Johnson & Graham, 2015; Mello et al., 2020; Sedwick, 2018; Xu & Talanquer, 2013). In Mataram, an inquiry was only implemented in one lab work lesson, so developing a design that uses more inquiry in teaching students is necessary.

Although inquiry can practice many skills for students, its application needs to consider the student's conditions. For students comfortable with the expository method, applying inquiry will make them uncomfortable, failing the investigation process (Cheung, 2011). Chatterjee's (2009) research found that using guide inquiry improved learning outcomes and better attitudes than open inquiry. This is an important concern when making innovations in biochemistry lab work, especially in determining the type of method to be used.

The lab work in Mataram has implemented 3 main stages: pre-lab, lab work, and post-lab. Pre-lab can be done in 3 ways: pre-lab lecture, pre-lab quizzes, and per-lab discussion (Agustian & Seery, 2017). Pre-lab is used to provide students with an overview of the investigation that will be carried out so that it provides a good understanding of carrying out work procedures, increases motivation, and the convenience of conducting investigations (Agustian & Seery, 2017; Almorth, 2015; Kelly & Finlayson, 2007; Shallcross et al., 2013). In Mataram, lab work has undergone a pre-lab process, namely pre-lab quizzes. However, observations during biochemistry lab work showed that students did not understand the investigation procedure, so pre-lab quizzes were ineffective in lab work. According to Chittleborough et al. (2007), pre-lab quizzes must be accompanied by feedback regarding the responses given by students who will carry out the investigation. So far, pre-lab quizzes only include giving questions answered by students on a sheet of paper and giving an assessment without any

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feedback. Meaningful feedback is the response given to students through an explanation connected to lab work implementation. If the answers given by students are not correct, then the lecturer needs to provide instructions regarding the correct answers so that students can learn from their mistakes (Agustian & Seery, 2017).

The right pre-lab will have a good impact on the conduct of the investigation. The use of pre-lab lectures and pre-lab discussions through the preparation of an investigation design is more appropriate for higher education. Through the preparation of an investigation design, manual lab work is no longer needed because students understand work procedures without having to follow the steps in the manual lab work. Pre-lab makes students better prepared to conduct investigations so that procedural errors, mistakes in taking materials that cause repetition, and material waste will not occur.

The pre-lab implementation can be added with instructions related to handling chemical waste so that students understand it during the implementation of lab work. Students need to understand the handling of chemical waste to protect the environment. "green chemistry" must be applied in learning and biochemistry lab work. Preparing a chemistry curriculum based on "green chemistry" is currently a concern of educational practitioners to protect the environment from the dangers of chemical waste (Aubrecht et al., 2019). Green chemistry in chemistry learning is defined as an effort to minimize pollution sources from chemicals by (1) eliminating or reduction of the source of pollution, (2) recycling and reusing the chemicals, (3) treatment of waste to minimize its hazards, (4) the use of microscale chemistry, and (5) better management of chemical inventories in the laboratories (Goh, 2020). Minimum solvents use and discussing the relationship between a chemical hazard and its toxicity mechanism can be done in lab work (Anatas, 2016; Coish et al., 2016). Students who understand the investigation procedure can take the right materials to reduce the waste generated. The right decision in selecting and determining the solvent amount or reagent is part of green chemistry (Obhi et al., 2019). Green chemistry must be implemented into a culture in lab work activities to maintain security (O'Neil et al., 2021). Through discussion activities, students need to be given an understanding of the importance of green chemistry in order to increase their trust in laboratory settings that are safe for the environment (Sheppard, 2021).

Investigating the pre-lab stage can make students responsible for their investigation process. Lab work can be the stage of realization of the preparation for investigations that students do at the pre-lab stage. Although realizing the pre-lab stage is sometimes difficult, the experiences students feel can help them in their next investigation (McDonnell et al., 2007). If the student is successful in the lab work stage, the student has the confidence to be successful in the next investigation. Conversely, if students fail, they can learn from their mistakes to prepare themselves better for the next investigation process (Cheung, 2011; Galloway & Bretz, 2015). Lecturers and assistants can motivate students to better pre-lab processes. The involvement of lecturers must be an important concern, and assistants can undergo the workshop stage before the lab work is carried out (Velasco et al., 2016). The collaboration of lecturers, students, and assistants is important in supporting better lab work implementation (Rootman-le Grange & Retief, 2018).

The biochemistry lab work in Mataram carries out a post-lab by compiling an investigation report for each event. The investigation report format includes the program's title, introduction, tools and materials, work procedures, observations, discussion, conclusions, and bibliography. Reports are submitted to the assistant 1 week after the implementation of the lab work at each event. Preparing investigative reports on post-lab activities is a stage that can help students understand and construct new knowledge and ideas (Rodloff & de la Harpe, 2000; Sampson et al., 2013). However, preparing reports will be useless if the lecturers do not give feedback. Feedback is important in improving students' writing skills (Car, 2013; Newel, 1998). In addition, allowing students to gradually improve their writing can be an option to improve their ability to compile investigative reports (Gragson & Hagen, 2010; Van Bramer & Bastian, 2013; Wackerly, 2017).

CONCLUSION

The results of this study concluded that the implementation of biochemistry lab work at the University in Mataram had been carried out and followed the pre-lab, lab work, and post-lab stages. The dominant method is expository, although inquiry and demonstration are laboratory work methods. Students feel interested in lab work, but preparing investigation reports is less fun for

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them. The involvement of lecturers in the implementation of lab work needs to be increased at the pre-lab, lab work, and post-lab stages. Waste handling must be instructed to students to achieve environmentally friendly lab work.

Based on the research results, several things are recommended: 1) Reducing the dominance of the use of expository methods in biochemistry lab work and providing more opportunities for students to carry out the investigation process using inquiry methods or other methods; 2) Optimizing the pre-lab implementation as one of the stages of biochemistry lab work so that students have good readiness to initiate the investigation process; reduce the use of excess chemicals due to procedural errors in an effort to create environmentally friendly biochemistry lab work; 3) Provide instructions related to handling chemical waste in the learning process to achieve environmentally friendly implementation of biochemistry lab work; 3) Provide feedback on investigation reports prepared by students so that they can have good writing skills; and 4) Provide workshops for assistants so that they have knowledge in helping lecturers carry out guidance and evaluation of the implementation of biochemistry lab work.

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