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Reflective Thinking of Undergraduate Students in Microbiology Lab Experiments

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Abstract.
This study attempts to examine undergraduate students' reflective thinking while conducting microbiology lab activities. A collection of particular questions designed to elicit reflective thinking abilities were used in the context of microbiology lab activities to conduct this research utilizing a quantitative descriptive methodology. 32 undergraduate students taking microbiology classes in their fourth semester at a public university in Bandung, Indonesia, served as the study's subjects. The findings demonstrated that reflective thinking arose in microbiology lab studies at the cognitive presence stage's resolution phase. Even so, just a small portion (6%) of all the introspective remarks that students have written, had the look of reflection. Students frequently consider the triggering event (49%) and exploration (32%), in that order. The conclusions of this study suggest that microbiological lab activities should be created in a way that promotes the growth of reflective thinking by giving students the chance to perform more challenging laboratory tasks in addition to completing experiments.

Keywords: reflective thinking, microbiology, lab experiments

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1. INTRODUCTION

Reflection is important for students to deepen their learning [1]. Students consider and comprehend what they have learned and why it should be learned when they reflect on their learning. Throughout their lives, learners are continually exposed to new experiences; as they reflect, they look back and connect one event to the next by comprehending their interconnection [2]. Reflective thinking can aid students in enhancing their academic performance, according to various research [3, 4]. The capacity to reflect is related to the capacity to enhance learning from prior experience and knowledge in order to enhance future learning procedures. Through (a) making connections between new knowledge and prior understanding, (b) thinking conceptually and abstractly, (c) using specific strategies to complete assignments, and (d) understanding their own ways

of thinking and learning strategies, reflective thinking aids students in the development of higher-order thinking skills [1, 5].

Reflective thinking is typically focused on real-world issues that raise doubt and confusion before offering potential solutions [1]. Reflection helps students gain the critical thinking abilities needed for practice and decision-making. Reflection empowers students to take charge of their own educational requirements, promoting career advancement, problem-solving, and lifelong learning. It is a procedure that enables people to look back on and evaluate their experiences in order to understand them better and, eventually, to practice more effectively [6]. The current study further establishes that reflective thinking aids students in enhancing their academic performance, problem-solving abilities, and science process skills [7, 8].

The ability to think reflectively is very crucial in life. Students in college should be able to think reflectively in their classrooms. This technique helps people take responsibility for their learning and identify their goals and plans of action. Individuals that can think reflectively will be able to display greater work performance [9, 10]. The development of reflective thinking in collage has been carried out in different types of lectures, for example, through portfolios, reflective writing, collaborative online learning, and other ways [2, 3, 11, 12]. However, in the context of learning in the field of biology, there have not been many studies on integrating reflective thinking into experimental activities and laboratory research, notably in the microbiology lab. Microbiological investigations and lab activities utilize science-process skills. By cultivating reflective thinking, students will be more effective in gaining knowledge and skills.

In typical classes, practical activities in microbiology laboratories involve students working in groups [6]. Interaction during the practicum process is particularly goal-oriented, which focuses on managing and finishing work or tasks. Most of the discussion during the practicum focussed on procedural concerns related to conducting experiments and how to maintain laboratory equipment [13]. By introducing reflective activities into group work, students have the opportunity to apply what they have learned through reflective activities so that they can increase the quality of their duty to learn in the future [6, 10].

In practice, instructors rarely examine students' reflective thinking when carrying out experiments; hence, reflective thinking skills have not been cultivated. The data on reflective thinking in this laboratory activity process can be tested by administering a form of test concerning procedural knowledge that directs students to reflect on their experiences in carrying out laboratory activity. The major purpose of this research is directed by research questions: What are the qualities of students' reflective thinking

skills in carrying out microbiological laboratory activities? In this study, reflective thinking is reviewed in terms of cognitive presence, one of which is reflection.

2. RESEARCH method

2.1. Overview of Design Study

The subjects in this study consisted of 32 students enrolled in 4th semester at a public university in Bandung, which represented the total number of students who contracted microbiology courses and attended microbiology lab classes. Students participate in five practicum topics as follows:

1. techniques for preparing microbial growth media,
2. microbial inoculation and isolation techniques,
3. bacterial cell staining techniques,
4. quantitative and qualitative tests of coliform, and
5. microbial resistance tests.

These five practicum topics were carried out in six weeks, one of which was the topic of inoculation and microbial isolation carried out independently by students in their homes due to face-to-face restrictions course during the pandemic. Students attend a 100-minute lab experiment every week and they work in six groups, with six members per group.

Data Collection

During the weeks of lab experiment, researchers participate in the practicum process and take on the role of laboratory activity supervisor as well as observer. After the implementation of the practicum in week 6, the researcher gave an explanation to the students about the study and informed about the procedure for filling out research instruments.

The research instrument consists of a set of reflective thinking questions designed according to reflection indicators in the cognitive presence resolution phase. The resolution phase itself is the highest level of cognitive presence. In full, the phases of cognitive presence are: Triggering Event, Exploration, Integration, and Resolution [14].

The following are detailed questions that lead to explore reflective thinking skills.

1. In order to obtain a good negative staining result, in what step do you think most determines the success of the staining?

Table 1: Cognitive presence phases and indicators [14].

Cognitive presence phase	Indicators	Socio-cognitive processes
Triggering Event	Recognise problem	Presenting background information that culminates in a question
Exploration	Brainstorming	Adds to established points but does not systematically defend/justify/develop situation
Integration	Connecting ideas, synthesis	Justified, developed, defensible, yet tentative Hypotheses
Resolution/ Reflection	Vicarious or real-world application of solutions/ideas Reflection	Defending why a problem was solved in a specific manner Reflecting on learning content and outcomes Reflecting on learning processes

2. In your opinion, what is the most important factor in determining the success of giving a comparison dye (safranin) in Gram staining?
3. In your opinion, what is the importance of heating in the spore staining procedure?
4. In your opinion, what improvements could you suggest in increasing the success of spore staining?
5. In your opinion, what is the most appropriate improvement suggestion to prevent pure bacterial cultures from being contaminated with other microbes during the staining procedure?
6. In your opinion, what procedure should be improved in Gram staining so as to increase the binding success of the reference dye?
7. If you were asked to culture bacteria that are tolerant to heavy metals, what procedure would you need to modify from the procedure you have studied?
8. What suggestions can you give to increase the display resolution of bacterial observations under a microscope?
9. For the success of detecting the presence/absence of coliform bacteria in the sample, what is the most important thing to do?
10. If you were asked to test the antimicrobial activity of an extract of a plant (eg betel leaf extract), what procedure in the resistance test could you modify?

In addition to being asked to provide answers that are considered correct, students are also asked to write reflective statements as an explanation or reason for giving the answer. Reflective statements as the answer are important to provide an overview of how the reflection process occurs when students answer questions on questions. Asking

reflective questions provides an opportunity to monitor the level of student knowledge, the use of resources in the learning process, and the achievement of learning outcomes. Then the best considerations and decisions can be taken regarding how to improve the learning process and learning outcomes [15].

2.2. Internal Validity and Ethical Consideration

The research instrument developed was reviewed by two validators who have expertise in higher order thinking skills and expertise in microbiology. The validator provides input regarding several question items that:

"Questions must be able to explore reflective thinking skills in the context of applying microbiology lab skills"

"Questions must pay attention to the correctness of concepts and procedures in the microbiology lab".

"Questions should represent most topics in microbiology laboratory activity "

By paying attention to the input given by the validator, improvements were made to the item items so that the two validators agreed that all item items were feasible to use.

Ethical considerations in this study are carried out by ensuring that all students involved in this study obtain information about the study and collect data from researchers. Participation in this study is voluntary, without any coercion and consequences for the assessment of student learning outcomes.

Data Analysis

Data analysis was concentrated on the accuracy of the answers given by the students as well as writing their follow-up explanations on the answers given. The process of analyzing reflective writing in student answers is carried out to identify four general types of cognitive presence in reflective statements, each of which is then examined in each cognitive process with a rubric referring to cognitive present regarding phases and indicators [14]. For this reason, qualitative analysis is dominant in this study, besides quantitative descriptive analysis is also carried out to see the score obtained both from the accuracy of the answers and from the student's reflective writing.

3. result and discussion

Researchers involved in the experimental process also understand practical procedures, take role as guide and also as observer. At the end of the sixth experiment, the

researcher gave test instruments to students, conducted data analysis, so that cognitive presence results were obtained as shown in Table 2.

Table 2: Cognitive presence analysis from students' answer sheets.

Cognitive presence phase	Indicators	Percentage of Posted Answers
Triggering Event	Recognise problem	49
Exploration	Brainstorming	32
Integration	Connecting ideas, synthesis	12
Resolution/ Reflection	Vicarious or real-world application of solutions/ideas	6

Table 2 shows the results of the analysis of students' answers to reflective thinking questions in the context of the microbiology laboratory procedures they have done. Students choose the correct answer based on the process of thinking about the answer to the question based on their knowledge and practical experience, then write down the accompanying explanation/reason.

The results of the analysis show that the first phase in the inquiry process, namely triggering, appears with the highest frequency, which is 49% of the total student writing. This number indicates a relatively large number compared to other phases. This phase is the most basic phase in marking cognitive presence. In the context of laboratory activity implementation, students at least have experience in the process so that they can recognize the context of the problem asked in the question.

The next phase that emerged as the second most coded was the exploration phase (32%), namely the brainstorming indicator. This cognitive process is characterized by the ability to provide additional explanations regarding the points referred to in the main answer, but has not been accompanied by a systematic ability to maintain logic. The integration phase appears in 12% of the answers, namely the ability to connect ideas (synthesis). In the context of this study, it is characterized by the ability to justify, defend, and develop the main idea but is temporary hypothetical. This phase appears relatively little with the last phase in the cognitive process, namely resolution and reflection. Reflection is characterized by the ability to maintain why a problem is solved in a certain way. This last phase only appeared as much as 6% of the overall student reflective answers.

Reflective statements in this study are important to provide an overview of how reflective thinking processes appear in students' cognitive structures. Several educational researchers have suggested that the introduction of writing activities in science classrooms and laboratories creates unique opportunities for students to develop

argumentative reasoning skills and become active and reflective learners. analytical writing can help students organize their ideas into a more coherent and interconnected conceptual framework [16]. As the main data in this study, here are some samples of student answers in each phase of cognitive presence.

Table 3: Samples of student reflective answers in each phase of cognitive presence.

Cognitive Presence Phase	Students' reflective writing sample
Triggering Event	*Question:* What is the most important factor in determining the success of providing a comparison dye (safranin) in Gram staining? *Answer:* Decolorization using 96% alcohol, because alcohol will wash all the primer colors that are not bound to the cell wall so that it can then be stained by safranin.
Exploration	*Question:* What is the most appropriate improvement suggestion to prevent pure bacterial cultures from being contaminated with other microbes during the staining procedure *Answer:* Ensure that the culture tube is passed over a Bunsen flame before and after taking the culture suspension. **The reason is** because at the time we take the culture suspension, the culture tube is completely opened so that the risk of contamination is very high. Bringing the mouth of the tube closer to the Bunsen fire can minimize contamination because it can kill bacteria in the air and the mouth of the tube
Integration	*Question:* If you were asked to inoculate bacteria that are heavy metals tolerant, what procedure would you need to modify from the procedure you have studied? *Answer:* **The procedure that will be modified** is the procedure for making media because to test bacteria that are tolerant of heavy metals, it requires enriched-media with heavy metals. The presence of bacteria in the media after incubation will be an indication, only the bacteria that are tolerant to heavy metals can grow, otherwise bacteria that are intolerant will not grow.
Resolution/ Reflection	*Question:* In your opinion, what procedure should be improved in the Gram stain so as to increase the binding success of the reference dye? *Answer:* **The procedure should be improved is about washing with alcohol must be exactly at the time needed.** Washing bacterial smears using alcohol is very important, because at that time alcohol serves to dissolve fat. In gram-positive bacteria (+), the fat is little so that it will dissolve and the protein will be dehydrated so that the pores are closed, while in gram-negative bacteria (-), there is a lot of fat so that when washed with alcohol, the pores are large which are not covered by dehydrated protein, so it will be stained. by safranin, because the crystal violet and iodin have been lost due to the decolorization earlier. If the decolorization is not on time, it could be that the gram (-) fat bacteria will not dissolve and the protein will not be dehydrated, so that the pores open and the crystal violet and iodin will disappear and the bacteria will be stained red by safranin.

In the integration phase, 12% of students' reflective writing answers indicated the ability to relate the work experience with microbes that had been done to new situations that had never been done. In the sample of student writing in Table 3, students were faced with a new situation, namely growing bacteria tolerant of heavy metals which had never been done before. However, with the learning experience from the previous laboratory activity, comes the ability to integrate past experiences with opportunities in

this new situation. Although there are still very few students who are able to reach the integration stage.

When exploring indicators of cognitive presence which also have reflection in them, it is clear that students in this study still tend to have the ability to recognize and express knowledge that is still developing at a lower level. Meanwhile, it is still lacking in achieving higher levels such as integrating and reflecting. As previous studies, that reflection is a process associated with higher order thinking skills, and can be coded as higher critical thinking skills, in the resolution phase, teachers can facilitate the development of thinking skills that are lower [14]. Reflection basically tends to be difficult to observe in traditional learning, and is also rarely expressed by students. So Garrison and Anderson suggested asking students to create reflection pieces to illustrate their contributions and experiences in learning.

The example of the fourth statement shows the socio-cognitive process of reflecting on the learning content and outcomes related to knowledge acquisition, in which learners identify the improvement of their knowledge and skills in the subject area. Learners must be able to articulate specifically what they have learned and the relevance of this new knowledge. Lipman argues that reflective thinking 'involves thinking about the procedure at the same time as thinking about the subject matter' [14].

TABLE 4: Descriptive statistics comparison: Laboratory procedural knowledge score and reflective statement scores.

	N	Minimum	Maximum	Mean
Lab procedural knowledge score *(Range 0-100)*	32	10	100	67, 2
Reflective statement scores based on cognitive presence (*Range 0-100)*	32	2,5	70	28,8

Based on the data in table 4, it is known that the lab experiment skill test scores tend to be higher than the scores on the reflective statement writing that supports each answer given. This data provides information that students basically have a good understanding of microbiology lab procedures applied in experiments, but in expressing their cognitive presence and reflective thinking related to the answers given are still under the ability of the lab itself. After practicum, students are more likely to read the course material and consider more carefully what they will get from my studies in order to stay focused properly. But they lack reflection on what went well in practice; and they are more likely to just learn something without thinking about the most appropriate learning style. In addition, college students spend more time looking at the evidence to reach their own conclusions.

The results is in line with previous study, that even though students are successful in lectures, they have not yet internalized the reflective thinking process to understand the learning experiences they have gone through [17]. Also, Other study showed that students stated that critical analysis carried out in the laboratory during practice sessions would be useful as a tool to deepen their reflective practice [18]. Overall, reflection can also be an effective tool for enhancing practical skills and should be further explored in a laboratory context.

So far, lecturers may assume that students are able to think and understand their learning experiences through reflective thinking [17]. However, the results of the studies show that lecturers must reconsider and rearrange lecture questions and topics that can encourage reflective experiences earlier. As soon as student perceptions begin to broaden along with in-depth reflection, lecturers can improve and push towards more independent reflection. This supports that guided reflection is still needed by students in higher education [19].

In the process of reflective thinking, students must play the role of active decision makers with the lecturer as a facilitator and motivator [9]. This decision-making process must of course be based on considerations based on experience and appropriate references. The lecture process needs to be enriched with various methods so that it can help students increase their involvement in the learning process [9].

Reflective thinking should be encouraged and supported through learning environments and learning activities [18]. Koszalka describes several characteristics of the environment and learning activities that can encourage the development of reflective thinking, namely: (a) providing sufficient waiting time for students to reflect when responding to inquiry activities, (b) providing emotionally supportive environmental support for reevaluation, (c) provide authentic tasks involving unstructured data to encourage reflective thinking, (d) provide explanations to guide students to think about the process during exploration, (e) provide an unstructured learning environment to provoke students to explore what they think is important, (f) provide social -learning environment, for example small group work to allow seeing other people's point of view, and (g) providing a reflective journal to write down students' positions [20].

In the context of microbiology lab activities, the study conducted by Xu and Talanquer showed that the level of experimental investigation affects student reflection activity [16]. Thus, experimental activities need to be designed in such a way as to facilitate the development of reflective thinking through challenging lab exploration and experimental activities. Good laboratory activities should be able to provide opportunities

for students not only to complete experiments, but also the opportunity to experience more complex laboratory experiences.

4. CONCLUSION

Based on the study, students' reflective thinking in the context of microbiology lab experiments has not dominated the cognitive presence process. Overall, reflection can be an effective tool for enhancing practical laboratory skills and should be further explored in a laboratory context. Reflective thinking should be encouraged and supported through the learning environment and learning activities. For this reason, practicum activities need to be designed in such a way as to facilitate the development of reflective thinking through challenging lab exploration activities and experiments.

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