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Portraying Critical and Creative Thinking Skills of Chemistry Teachers Candidate in Biochemistry Laboratory Activity

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Abstract.
Critical and creative thinking skills are two important aspects that must be exerted to prepare globally competent chemistry teacher candidates. Developing global competence is about how to see teaching practice using a new lens. Minimizing the role of lecturer and making students more active through experimental activities can facilitate the development of both critical and creative thinking skills. Therefore, this study aims to picture the critical and creative thinking skills of chemistry teacher candidates and their motivation in biochemistry laboratory. This case study research involved 38 students' chemistry teacher candidates as research participants. The data was collected through curriculum document analysis, observations, interviews, and tests for measuring critical and creative thinking skills in biochemistry laboratory activities. Curriculum analysis revealed that the majority of the procedures used in biochemistry laboratories are in cookbook lab-style format. A step-by-step laboratory procedure with a dominant expository method was observed during the teaching process, which was designed to develop only critical thinking skills. The results indicate that critical and creative thinking skills in biochemistry laboratory activities are at a low level, with the average scores obtained through the tests are 45.20% and 33.80%, respectively. Students' motivation to study in the laboratory was found at a moderate level of 68.00%, suggesting a moderate desire to learn and the satisfaction experienced in the learning process and learning outcome.

Keywords: portraying critical, creative thinking skills, biochemistry laboratory activity

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1. INTRODUCTION

Education is a community and national effort to enhance students' potential as well as to educate the younger generation for a better future survival for society and the nation. Updates in many disciplines of education are carried out regularly basis in order to improve the quality of education in Indonesia for this reason. Indonesian education is currently experiencing a shift in the flow of globalization from a society

with a traditional lifestyle to a society with a more modern lifestyle. Furthermore, the formation of the ASEAN Economic Community (AEC) will result in more competitive human resource competition. In order to compete in an increasingly competitive world, education must produce graduates who can compete not only with domestic workers but also with foreign workers, both at the ASEAN and global levels. Higher education, as a provider of educational services, is currently making several advances in ensuring the quality of its graduates, one of which is international accreditation. This international accreditation requires that the curriculum in higher education be prepared based on outcomes (outcome based education) by considering the application of science and technology and skills development in the 21^{st} century [1].

The internal challenges confronting Indonesian education, on the other hand, are that students' thinking skills in Indonesia are mostly in the category of basic thinking, and the learning process has not developed higher order thinking skills (HOTS). As evidenced by PISA results, Indonesia was ranked 69^{th} out of 76 countries assessed in 2018. These findings are based on an evaluation of the cognitive aspects of math and science subjects, with the questions emphasizing HOTS. HOTS is critical in preparing superior and high-quality human resources to compete globally and competitively. Critical thinking skills and creative thinking skills are significant aspects of HOTS in science learning [2-4]. Both of these abilities have been sought to be added to science education, either through curriculum integration or learning innovation.

Critical and creative thinking skills are aspects of 21^{st} century learning apart from collaboration and communication. Someone who has critical and creative thinking skills will be able to analyze arguments, solve problems, find cohesive and logical reasoning, and also produce something creative and original. Therefore, teachers who have these two skills will be a positive effect on the learning process, so that the quality of learning will increase. Meanwhile, Chemistry learning which is part of science learning cannot be separated from critical and creative thinking skills. This is because critical and creative thinking skills are concurrent influences in science learning when viewed from the point of view of science as a product and science as a process [4-5].

Biochemistry laboratory activity is a work that is linked with Biochemistry courses, which are required courses for prospective chemistry teachers. This course is a debriefing material for prospective chemistry teachers who want to conduct learning in high school on the topic of organic compound molecular structure and reactions [2]. Many previous studies on critical and creative thinking skills in chemistry and biochemistry laboratory activity have been carried out. Previous research has indicated that critical and creative thinking skills are not developed simultaneously in biochemistry laboratory

activity including: Sanchez developed and used control charts as a tool to analyze and validate student laboratory activity results so that they can detect and correct errors by critical thinking [3]. The use of laboratory activity modules designed for students during the COVID-19 pandemic can provide opportunities for them to practice research-relevant skills such as finding primary literature sources, creating test samples, explaining unexpected experimental results, and revising experimental procedures to improve methodology. Ultimately, these modules provide educators with additional tools for teaching experimental chemistry outside the laboratory [4].

Likewise, with case studies regarding the achievement of critical thinking skills or creative thinking skills. Previous research has investigated or analyzed thinking skills developed in learning, unfortunately the investigation is still focused on only one skill (critical thinking/creative thinking). Li et al, analyzed students' creative thinking skills developed through technical education in vocational high school education [5]. Meanwhile, Zhou et al. investigated the critical thinking skills of teachers at the pre-service and in-service levels [6]. Previous studies have only focused on one skill, be it critical or creative thinking skills. On the other hand, beside of the cases above, to portrait both of the critical and creative thinking skills of chemistry teachers' candidate in biochemistry laboratory activity. The results of this study will contribute to the innovation of the biochemistry laboratory in developing the critical and creative thinking skills of chemistry teacher candidate.

2. RESEARCH METHOD

This current work was employed a case study research method that aims to describe the real situation that occurs in the overall biochemistry laboratory activity. Meanwhile, the focus of the observation is to analyze the critical and creative thinking skills of chemistry teachers' candidate, and to reveal student responses to biochemistry laboratory activity. The participants in this study were 38 chemistry teachers' candidates, who were taking biochemistry lectures and laboratory activity at the State University of Ambon-Indonesia, as well as a lecturer in a biochemistry course. Data was collected through analysis of curriculum documents for biochemistry courses; laboratory activity observation data both before, during the process and at the end of the laboratory activity; data on critical and creative thinking skills; and data on students' responses.

The instruments used in data collection are curriculum documents, laboratory activity observation sheets, tests of critical and creative thinking skills, questionnaire, and form of interview. Document review is done by analyzing the curriculum, including objectives,

content of laboratory activity material, process, and evaluation. Observations of the implementation of this laboratory were carried out of four meetings on the experiments of carbohydrates, proteins, enzymes, and lipids/cholesterol

The validity and reliability feasibility of the test to evaluate critical and creative thinking skills have been met [7-8]. Questionnaire responses from students to the biochemistry laboratory activity, including the laboratory activity guide (validation of content, language and organization of explanations, structure of the laboratory activity guide, benefits of the laboratory activity guide), the laboratory activity process, interest and motivation, and the laboratory activity assessment to assess critical thinking skills and creative thinking.

The obtained data were systematically and comprehensively analyze by triangulating data sources. Triangulation of data sources is used to determine the validity of the data obtained by comparing the correctness of data obtained for the same purpose from different instruments. All of the data obtained were analyzed to confirm each findings and narrow down to generate inferences.

3. RESULTS AND DISCUSSION

Biochemistry is one of the required courses that should be taken by chemistry teachers candidate at the University where the research is located. This course aims to provide an introduction to the concept of bioenergetics, the structure and function of biomolecules (carbohydrates, proteins, lipids, nucleic acids) as well as the metabolism of biomolecules and genetics. The biochemistry course includes theoretical and practical activities, with a 3 credit of 2 credits of implementing theory and 1 credit of practical implementation. The results of survey showed that biochemistry lectures, were carried out separately, with theoretical lectures held at the beginning and laboratory activities carried out for 4 meetings in accordance with the experiments contained in the laboratory activity guide that had been prepared by the course lecturer team before the end of semester exams.

Curriculum documentation analysis is one of the data collection techniques used to investigate the facts to be studied by examining existing documents. In qualitative research, document review can be used as the primary data source or as supplementary data. The documents reviewed in this study include the Lesson Plan, laboratory activity guide, and analysis of the assessment rubric. The results of the curriculum document analysis are shown in Table 1. Based on the results of the analysis of the lesson plan document in the biochemistry course, there are two main materials, including cells, and the structure and function of biomolecules consisting of carbohydrates, amino acids, and

proteins, enzymes, lipids, and nucleic acids. In the course learning outcomes, it has been illustrate the critical and creative thinking skills that are taught to students. However, not all material content in biochemistry courses is carried out by laboratory activity. Carbohydrates, proteins, enzymes and lipids/cholesterol are the materials carried out in the laboratory activity based on the guide carried out not involved aspects of critical and creative thinking skills.

Table 1: Document curriculum analysis.

Review Document	Yes	No	Thinking Skills	
			Cognitive Process Dimension	**Knowledge Dimension**
Lesson Plan	√		**Critical and Creative** (Analyze, evaluate and create)	Conceptual, and procedural
Practical Guide	√		**No Critical and Creative** (Remember, understand and apply)	Procedural
Assessment Rubric		√	**No Critical and Creative** (Remember, understand, apply)	Conceptual

The practical guide used at the moment has not changed for approximately 8 years due to a lack of tools and materials, so only a few experimental procedures can be performed, including carbohydrate testing, protein testing, enzyme testing, and cholesterol determination. The practical guide consists of a cover, a table of contents, laboratory rules, and experimental material. The experiment section has been equipped with an experiment title, theoretical basis, experimental objectives, tools and materials, procedures, observation data sheets, and discussion. The data sheets and discussions placed in each experiment greatly facilitate the practitioner in writing the observations, analyzing and explaining the observations in the laboratory guide without making separate reports. The results of the analysis of the laboratory activity guide document revealed that critical and creative thinking skills were not trained. This was because all work procedures were available and students only followed the experimental instructions that were already obtainable. The expository approach is an approach that is still used in the context of teaching in laboratories by several universities in Indonesia. Students, in this case, are asked to test and analyze data based on laboratory activity guidelines that have been set by the instructor or teacher. This process actually provides an opportunity for students to develop their practical skills by using various laboratory equipment, mixing solutions and making observations [9]. Meanwhile, the laboratory activity assessment rubric was not found in the documents analyzed. This is confirmed

by the findings of interviews with five participants, who discovered that the laboratory activity evaluation rubric was never given to students previous to the laboratory activity, hence students were unaware of the laboratory activity assessment indicators.

Observation of the implementation of biochemistry laboratory activity is one of the main activities in biochemistry learning that aims to improve students' abilities in terms of attitudes (affective) and skills (psychomotor). There are four important reasons for implementing the laboratory activity, consist of: (1) it can generate students' learning motivation; (2) it will develop basic skills of conducting experiments; (3) it become a vehicle for learning scientific approaches; and (4) it will support the subject matter [10]. The biochemical laboratory activity was observed for four meetings and included carbohydrate tests, protein testing, enzyme activity testing, and blood cholesterol level determination. Table 2 shows that there are indicators of critical thinking skills observed in the results of the analysis of laboratory activity, but there is no visible indication of creative thinking skills. Laboratory activity preparation consists of introducing students to the instruments and materials used in the laboratory, as well as working methods for each experiment and laboratory occupational health and safety. Critical thinking skills were discovered during the laboratory activity preparatory by the lecturer's questions regarding how to cope with chemical spills during the laboratory activity. The student did not respond to the question, so the lecturer continued to describe how it worked using the processes in the laboratory activity guide.

In practical activities, critical thinking skills are still observed through questions given by lecturer assistants to students about making 10% glucose solutions. In addition, critical thinking skills are observed when student A is able to provide answers to questions and provide solutions to problems that occur in Benedict's and Tromer's tests on the isolation and hydrolysis of carbohydrates. However, creative thinking skills are not observed in the laboratory activity process. This is because the procedures for each experiment, both carbohydrate testing, protein testing, enzyme activity testing, and determination of blood cholesterol levels, have been described in full in the laboratory activity guide, therefore students just follow these steps and observe the experimental results. Furthermore, critical and creative thinking skills were not observed in the final activity of the laboratory activity because the assistant demonstrated how to analyze the observations and write a final report based on them. Meanwhile, students only wrote explanations and did not ask questions.

The findings of the observation show that the implementation of the laboratory activity only provides critical thinking skills. Observed indicators of critical thinking skills include focusing questions, asking and answering questions about an explanation or

Table 2: Laboratory implementation activities and its relationship with thinking skills.

Activity	Thinking Skills
Pre-Laboratory Activity The lecturer takes an outline of the experiments contained in the laboratory guide and introduces the tools and materials used in each experiment. The chemistry teacher candidate asks about handling spilled chemicals while doing laboratory. The chemistry teacher candidate listens to the practical assistance delivered by the lecturer. The lecturer conducts testing of the procedures that have been made and prepares the tools and materials needed for the implementation of the laboratory.	Identifying assumptions (critical thinking)
Laboratory Activity Process Lecturers and assistants explain the working procedures of each experiment to students. The lecturer asks about how to make a 10% glucose solution. None of the students answered the question, and the lecturer continued to explain the work procedure without giving an answer. The chemistry teacher candidate conduct an experiment in accordance with the procedures developed and demonstrated by the lecturer assistant. The assistant notices an error in the experiment and asks questions on how to solve the problem so that the experimental results obtained are consistent with the current reaction. Student A responds by providing answers and solutions to problems encountered in the lab by increasing the temperature so that the reaction can run and give a color change in the test tube.	Focusing questions (critical thinking) Observing and focusing questions (critical thinking) Answering questions by explaining existing problems (critical thinking)
End of Laboratory Activity The assistant provides an explanation of the preparation of the final laboratory report and how to analyze the experimental results obtained in the experiment. The chemistry teacher candidate should observe and record all explanations without asking questions or providing additional explanations.	

critical challenge, and identifying assumptions. Observations of the laboratory activity implementation also revealed that eight students were active during the laboratory activity process, both in answering and asking questions and conducting experiments, in four observations.

Overall, based on observations, it is possible to conclude that the laboratory activity only emphasizes critical thinking skills; there are no visible activities that lead to creative thinking skills. Lecturers and assistants use presentation and question-and-answer sessions. The analysis of critical and creative thinking skills was also confirmed using the critical thinking skills test and the creative thinking skills test, which are shown in Table 3 [9].

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The analysis of critical and creative thinking skills test results revealed that the average critical thinking skills score was 45.20 percent and the average creative thinking skills score was 33.80 percent. The findings of this study indicate that critical and creative thinking skills are lacking in the biochemistry laboratory activity. This is due to the fact that the biochemistry laboratory activity still employs the expository method, namely the use of a laboratory activity guide prepared by the course teaching team and assisted by laboratory activity assistants. Although, several indicators of critical thinking were observed both before and during the laboratory activity process,

Table 3: Critical and creative thinking skills score on biochemistry laboratory.

Critical Thinking Skills		Creative Thinking Skills	
Indicator	**% Score**	**Indicator**	**% Score**
Elementary clarification	54	Fluency	45
Basic support	51	Flexibility	28
Inference	47	Elaboration	41
Advance clarification	40	Originality	21
Strategy and tactics	34		
Average score	45,2	**Average score**	33,8

including focusing on questions, identifying assumptions, observing and considering an observation report, and asking and answering questions about an explanation or challenge. These indicators are constructed through question and answer activities conducted by lecturers, laboratory assistants, and some students during laboratory activity, but these activities were not conducted by all students [11].

According to document analysis, the biochemistry laboratory activity guide contains procedures or experimental steps in a systematic method, which does not allow students to develop or design work procedures independently. This type of laboratory activity only clarifies the results obtained with the previously studied theory. Furthermore, based on observations of classroom learning, lectures continue to be centered on the lecturer. In class lectures, the presentation and question and answer methods are always used. The lecture and question and answer method is a teaching approach in which the lecturer explains the learning material by demonstrating arguments and providing instances of questions, while the students listen and repeat the patterns presented. The integration of question and answer activities into the lecture approach did not allow all students to participate actively in lectures. This supports prior results that show lecture-centered learning does not improve critical and creative thinking abilities [4,9]. This is consistent with the findings of eight interviews with respondents who stated that biochemistry lectures did not use any other learning methods besides presentations and questions and answers. Indirectly, this has a significant impact on the students' ability to think critically while working in the laboratory. Students are not given the opportunity to form their own knowledge through laboratory learning experiences.

The results of the questionnaire analysis of student perceptions on the aspects of critical and creative thinking skills also support the results of the study that the biochemistry laboratory activity carried out was very lacking in improving critical thinking skills (35.5%) and creative thinking (28.5%). These results indicate that the development of critical and creative thinking skills must involve students in the learning process and

laboratory activity, so that students will get a good learning experience in shaping their knowledge. Student-centered learning will improve their critical and creative thinking skills. Rodriguez et al, show that learning in the laboratory should be able to improve students' critical and creative thinking skills if the laboratory curriculum is developed and modified using approaches and methods other than expository, such as science practice, including pre-lab and post-lab questions [12]; team and project-based learning, in which students work collaboratively to propose, design, and solve their own experimental problems [13]; Moreover, a problem-based approach to teaching advanced chemistry in the laboratory has a positive impact on improving students' critical thinking [9].

The students' interest and motivation to study in the biochemistry laboratory is actually good, as obtained from the analysis of the perception questionnaire on aspects of student interest in the biochemistry laboratory activity. Students expressed a strong interest in and motivation for the biochemistry laboratory activity (68%). This is reinforced by the results of interviews with respondents. They stated that the biochemistry laboratory activity increased their interest and motivation in learning and provided benefits for increasing competence as teachers candidate and argued that biochemistry lectures, including the biochemistry laboratory, would be useful as a provision for them to continue their higher studies. However, the lectures and laboratory activity carried out have not accommodated the interest of these students in improving their competence. The critical and creative thinking skills of chemistry teachers candidate need to be trained through each lesson, both in the classroom and in the laboratory. This is very important in preparing them to enter the world of work and global competition.

4. CONCLUSIONS

Biochemistry lectures, which include both theoretical and practical activities, are carried out separately. The results of the research through analysis of curriculum documents, laboratory observations, and tests show that the biochemistry laboratory activity does not emphasize the development of students' critical thinking and creative thinking skills. This is because biochemistry laboratory activity are carried out expository by referring to the laboratory activity guide and supervision from lecturers and laboratory assistants. The scores of students' critical and creative thinking skills were in the low category, namely 45.20% and 33.80%, respectively. The chemistry teacher candidates stated that they had a fairly good interest and motivation (68.00%) towards the biochemistry laboratory activity and that the laboratory activity provided benefits to improve their

competence as teacher candidates. Based on the results of the analysis of the critical and creative thinking skills of chemistry teacher candidates in biochemistry laboratory activity, it is necessary to conduct research to improve critical and creative thinking skills in an innovative and creative way laboratory activity.

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