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The Analysis of Creative and Critical Thinking Abilities of Future Teachers on Analytical Chemistry Laboratory Activity

Yeanchon Henry Dulanlebit[1,2], Liliasari[1]*, Hernani[1]

[1]*Doctorate Program of Science Education, Universitas Pendidikan Indonesia – Bandung, Indonesia*
[2]*Chemistry Education Study Program, Universitas Pattimura – Ambon, Indonesia*

ORCID
Yeanchon Henry Dulanlebit: https://orcid.org/0009-0004-8458-8741
Liliasari: https://orcid.org/0000-0001-7832-5698
Hernani: https://orcid.org/0000-0002-3724-5955

Abstract.
The ability to think creatively and critically is considered the main cognitive competency. This study aimed to measure the thinking ability of students (n = 33) who participated in a laboratory activity in analytical chemistry. Case study methods were used to collect qualitative data, which supports quantitative data. The student's creative and critical thinking abilities are measured by correlating the test result with their observations and responses. The results show that the student's creative and critical thinking abilities are qualified as sufficient. An average of 46.96% of the students could provide correct answers, with the highest percentage on mixture separation tasks (72.7%). The students also showed creative and critical thinking abilities in creating and defining the result after consideration, resolving problems, providing answers with sound reasoning, observing, creating combinations and objects, and detailed ideas regarding the task indicators. The students could also define terms, analyze questions, and adapt their approaches to resolve tasks. The abilities of some students to identify problems from several points of view are still considered low, and they need to be able to identify issues based on given pictures and assess topics from different perspectives. The laboratory activity should create more indicators to think critically and creatively about every aspect.

Keywords: creative thinking, critical thinking, abilities of future teachers, analytical chemistry, laboratory activity

Corresponding Author: Liliasari; email: liliasari@upi.edu

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1. Introduction

Thinking critically and creatively becomes essential in the learning process. Critical and creative thinking, one of the main competencies regarding gathering, evaluating, and utilising information effectively and precisely, has become a "vital necessity" in the 21st century. Thinking creatively differs from regular thinking, where critical thinking is more complex and has objectivity, utility, and consistency standards [1–3]. The ability to think

critically is significant when the teaching materials are based on investigative studies compared to regular teaching methods [4, 5].

Critical thinking is interpreted as being skilful and active through observation and communication of information and arguments, also identified as the ability to think on a higher level [6]. Thinking critically is a process that integrates the skill and knowledge to act and the ability to activate cognitive skills (analytical reasoning, problem-solving, and arguments) [7, 8]. Students who can research, analyse, and think critically are considered to have the needed cognitive skills. Critical thinking is used in problem-solving, summarising, calculating, and making decisions [9–12]. The development of skills in critical thinking aims for the students to gain a set of skills to increase their achievements and deeper understanding of their disciplines, including chemistry [1, 13].

Thinking creatively plays a vital role in innovation, creating ideas, and solving problems, whereas creativity aims to increase the student's performance and creative ideas [2]. Thinking creatively also means learning to find aesthetic and constructive statements regarding the views and concepts that focus on intuitive and rational thinking aspects towards information and means to explain them based on the original perspective of the thinker [14]. Creativity refers to thoughts, answers, or products that are original and useful. Students' creativity is dominant in how their cognitive ability will affect their creative thinking and performance [15].

The current learning process aims to develop creative and critical-thinking skills [5, 16]. The ability to think critically and creatively is considered the main cognitive competency. Creativity relates to the mental process, personality, and environmental characteristics that can be evaluated through their answers [17], whereas critical thinking relates to a complex method regarding higher-level reasoning. Creativity involves deductive and inductive thinking and problem-solving strategies to create new solutions. Critical thinking is considered a cognitive construct, implying inductive and deductive reasoning and the creative problem-solving process. Critical thinking may be associated with creativity in terms of conceptual or empirical [3].

Studies in universities nowadays are focused on methods to teach critical and creative thinking. The interviews with the students show that the practicum methods may increase their critical and creative thinking. However, there are still limited studies on how the student's critical and creative thinking skills are taught during practicum. This caused the students to lack problem-solving skills, which failed the internship [18, 19]. The students' critical and creative thinking of the students during training in the form of analysis, evaluation, and problem-solving may be achieved through performance-based

evaluations where the result of the review shows the students' ability in specific aspects [7, 20].

Practicum is a complex activity during the learning process that relates to theory, experiments, safety, and instrumentalisation. The critical and creative thinking aspects of the practicum are the cognitive ability to understand measurement data, the ability to observe, and the ability to express opinions. The critical thinking aspect may also be seen by following the data analysis in the the experiment report [21]. Creativity is a way to solve problems that leads to productivity achievement, whereas critical thinking may be measured through problem-solving, practical reasoning, and decision-making [3, 22]. The main factor in learning through practicum to measure the student's ability to think critically and creatively is the knowledge of the practicum supervisor. The supervisor must know 1) the procedure, technique, and safety, 2) the concept regarding the practicum, and 3) the students' way of learning [23].

The investigative-based learning model enables the students to explore, produce, and practice the concept to increase critical and creative thinking abilities. The studies of Sönmez et al. regarding the effect of an investigative approach during the practicum resulted in the students showing skills in problem-solving when planning the experiment, problem reconstruction, reasoning, and decision-making in every training. The students were also curious to find answers during the practicum [8].

The observation results show that the ability to think critically and creatively during the analytical chemistry practicum is essential for the students. According to them, activating practicum through analytical and critical questions will increase knowledge, experience, and skills in the laboratory. The training that may improve the student's critical and creative thinking to achieve study goals is essential. Therefore, this research aims to analyse the students' ability to think critically and creatively after performing an analytical chemistry practicum.

2. RESEARCH METHOD

The sample of this research consists of 33 students participating in the Analytical Chemistry practicum in the Chemistry Education Study Program of the Teachers' Training and Education Faculty at Pattimura University, Ambon. The research used mixed methods by simultaneously collecting qualitative and quantitative data, using qualitative data to support the quantitative data [8]. Qualitative data was collected using observation sheets, guided interviews, and questionnaires, whereas quantitative data was collected through test instruments.

The test instruments used to measure the student's competency regarding the ability to think critically and creatively are formed of 8 given tasks showing their ability to understand the practicum materials. Observation sheets were used to monitor the execution of the practicum and the scientific behaviours of the students regarding their critical and creative attitudes. Questionnaires to collect the students' responses about the execution of the training, interviews to delve into the students' ways of thinking and to evaluate their ability to think critically and creatively during practicum [8], also to clarify the opinions of the students as comparative data in the analysis of the questionnaires and test results. Quantitative analysis was done by calculating the percentage of responses for every question.

3. RESULTS and Discussion

The research was conducted to measure the ability of the students to think critically and creatively (n = 33) while participating in the analytical chemistry practicum. The student's ability to think critically and creatively was measured by correlating the test result with the result of observation and the student's responses. The research results show that the student's average cognitive ability after performing the practicum is sufficient. Furthermore, the student's ability to point out correct answers to every question is higher than their ability to provide reasoning for every solution.

Knowledge is essential in building critical and creative thinking concepts [24]. Among the eight multiple-choice questions with reasons, an average of 46.96% of the students could provide correct answers. In question number 1 about the aim of sample preparation, 21.2% of students answered correctly; for question number 2 about the factors that affect extraction, 51.5% of students answered correctly; in question number 3 about the process of gel-forming, 57.6% of students answered correctly, for question number 4 about the effect of concentration and pH level in adsorption, 42.4% of students answered correctly, question number 5 about analysis methods, 66.7% of students answered correctly, for question number 6 about the separation of mixture, 72.7% of students answered correctly, for question number 7 about the polarity in chromatography, 42.4% of students answered correctly. For question number 8 about distillation, 21.2% of students answered correctly.

The primary goal of higher education is the ability to think critically and creatively, where the ability to give relevant questions, define the problem, investigate evidence, analyse assumptions, synthesise information, draw conclusions, and provide arguments may be used in making decisions and solving problems [10]. From question number 1,

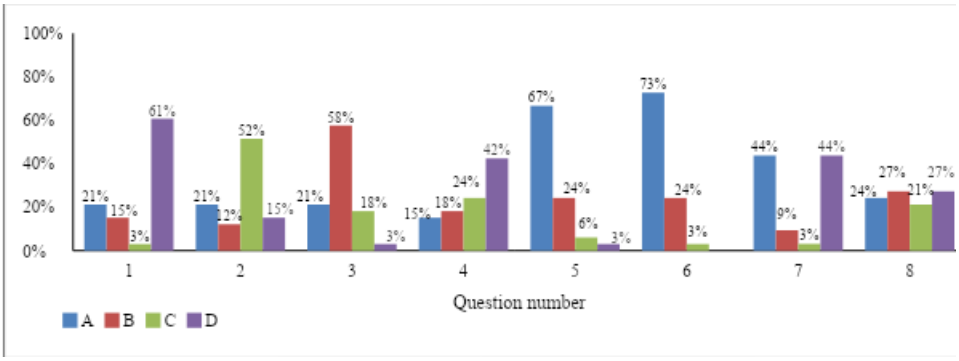

Figure 1: Percentage of the ability to think critically and creatively.

regarding the aspect of critical thinking in identifying assumptions and the ability to think creatively to see the issues from various perspectives, it is found that the student's ability to think critically and creatively is still low, where the students' explanation regarding the aim of sample grinding in the preparation process was to decrease the moisture content of the piece, which affects extraction, where only a small number of students gave the reason for sample grinding in the preparation process aims to increase the affected area of the seaweed with solvent during the extraction process. In question number 2, the factors that affect extraction are types of solvents, temperature, duration, and methods. The conclusion is that the student's ability to think critically and creatively is good. This is proven by their given answers and reasoning that show their ability to create and define the result of their considerations and to find various ways to solve the problem regarding the indicators to think critically and creatively for this question.

On questions 3 and 4, about the sample extraction process to form gel and the effect of concentration and pH level in the adsorption process, the students are found to be able to give correct answers and reason by the indicators of the ability to think critically in analysing arguments, observations, and giving considerations in the report, also their ability to think creatively in making irregular combinations from several parts or elements, also in detailing an object, ideas, or situations to make it more interesting, which is in accordance to the indicators for these questions. On questions 5 and 6, about the analysis methods to identify the concentration drop of metal ions and the separation of mixtures, the students can define the terms, consider a definition, and analyse the question, which are the aspects of the ability to think critically. The students can also explore the problems and change their approach or way of thinking, which are the aspects of thinking creatively and have been shown through their answers to this question.

On question number 7, about the polarity in chromatography, some students are still mistaken in choosing the possible criteria to solve the problem, which is an aspect of

critical thinking, and creating irregular combinations of parts or elements as part of the creative thinking aspect. The student's lack of knowledge causes this because they are unfamiliar with solvent variations based on their immobile and mobile phases. However, some students have shown the ability to think critically and creatively, as proven by their descriptions of the answers and reasoning for the question. On question 8 about distillation, the students were found not able to identify the problem based on the given picture, as the aspect of critical thinking, and also unable to evaluate a situation from different perspectives, as the aspect of creative thinking. The explanation of answers proves this, and the reasoning is still incorrect in defining the distillation principles. This question also reveals that the students are unfamiliar with solving questions using pictures, which can be used to measure the ability to think critically and creatively.

The test result shows that the analytical chemistry practicum produces indicators of thinking critically and creatively in every aspect [25]. On the element of giving explanations and building basic skills, the students could identify the questions, formulate possibilities of answers, and give reasoning for the given questions. However, in providing a further explanation, the students cannot express general issues but can draw conclusions based on the discovered facts; the students have also given detailed answers. Regarding managing strategy and tactics, the students have revealed the problems with the questions given. However, they lack creativity in solving problems and providing details. This is caused by the students' character when finding ideas and innovating based on the information received.

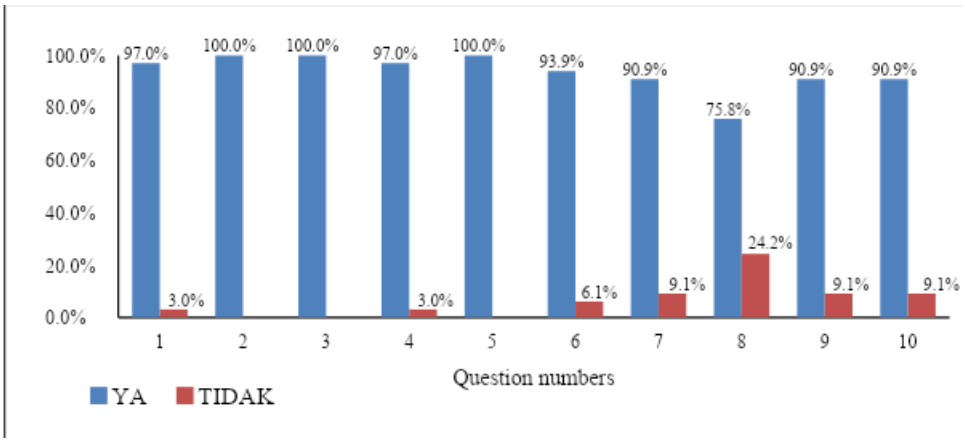

Figure 2: Response to students' critical and creative thinking.

On the evaluation based on performance and given responses, some questions were about analytical chemistry, analytical reasoning, and problem-solving that may train and improve the students' cognitive skills. By answering the questions, the students become skilled and active at formulating answers, creating summaries, and developing creative

ideas that may improve their critical and creative thinking abilities. However, some students still have difficulties understanding and working out the questions they need to conceptualise to measure their critical and creative thinking, including thinking at a higher level to answer every given question.

4. CONCLUSIONS

Based on the result, the student's ability to think critically and creatively during the analytical chemistry practicum is qualified as sufficient. An average of 46.96% of the students could provide correct answers, with the highest percentage on the separation of the mixture (72.7%). The students also showed the ability to think critically and creatively about creating and defining the result of consideration, finding solutions to problems, providing answers with the correct reasons, observing, making combinations, and detailing objects and ideas by the indicators of the question. The students could also define terminologies, analyse questions, and change approaches in problem-solving.

The ability of students to identify problems from different perspectives still needs to improve, as shown by their incorrect answers. The students also needed to be corrected in choosing solutions to create irregular combinations. Some students have shown the ability to think critically and creatively. The students could also not identify problems based on the pictures and evaluate a situation from different perspectives.

Analytical chemistry practicum created indicators of thinking critically and creatively about every aspect. However, the students need more ability to provide solutions to problems, details, and general issues that could draw conclusions based on the facts on the spect of giving further explanation. In the evaluation and responses of the students, some still need help understanding and working out the questions on thinking critically and creatively.

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