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Status of Prospective Science Teachers' Critical and Creative Thinking Skills in Energy and Its Integration Topics

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Abstract *– This study aims to assess the status of critical and creative thinking skills of prospective science teachers, particularly in the context energy and other integrated topics. A total of 76 prospective science teachers from a college in East Java, Indonesia, participated in this study. Data was obtained through essay tests, interviews, and observation sheets. The critical thinking skills test followed the Ennis framework, while the creative thinking skills test followed the Guilford framework. The data were analyzed using descriptive statistical methods. The results showed that the students' abilities in both skills were insufficient. They encountered difficulties in mastering critical and creative thinking skills across all indicators. These findings highlight the need to enhance teaching and learning strategies, with the goal of strengthening students' critical and creative thinking skills, as well as supporting them in developing their understanding and skills. The status of critical thinking skills and creative thinking skills is highly significant to be articulated, which calls for various efforts to improve them, especially in the topic of energy and its integration.*

Keywords: *creative thinking skills; critical thinking skills; energy and its integration topic*

I. INTRODUCTION

Integrated Science learning is generally an approach that combines various disciplines such as physics, chemistry, biology, and earth and space science into a comprehensive curriculum (Asrizal et al., 2018; Gunawan et al., 2020; Sun et al., 2014; Wong et al., 2022). This approach emphasizes the unity of scientific knowledge and encourages the combination of perspectives, concepts, and methods from various disciplines in understanding and interpreting scientific phenomena in everyday life. The implementation of integrated science learning emphasizes the importance of a broad scientific foundation in primary and secondary education to learn and understand natural science, which can then help in solving

problems requiring interdisciplinary solutions (Lee & Wan, 2022). The integration of science learning can benefit students in building a foundation of understanding and literacy, developing 21st-century skills, and various other positive benefits (Wallace & Coffey, 2019).

The implementation of Integrated Science learning lectures is aimed so that students acquire skilled competencies, both conceptually and procedurally, about techniques for integrating science learning. The goal is for students to be able to design learning tools that contain integrated science content and to design innovative science learning tools. However, in the process of designing integrated science learning tools, students often face difficulties, especially when dealing with less understood content, misconceptions in integrating science learning, differences in scientific backgrounds, and challenges in composing integrated science learning tools (Gunawan et al., 2019; Indrawati & Nurpatri, 2022; Rubini et al., 2019; Sun et al., 2014; Wei, 2020). Besides, there are some difficult topics to understand, such as the energy topic and integration of various other disciplines (Gunawan et al., 2019).

The challenges in the field emphasize the need for science educators to have a comprehensive grasp of unified knowledge. This is not only beneficial for learning activities but also enables the understanding and interpretation of everyday phenomena from various scientific perspectives. Students, in general, are expected to possess knowledge and skills in the field of science education, encompassing sub-disciplines such as physics, biology, chemistry, and earth sciences. This framework allows for integrated science learning to have the characteristic of integrating its sub-disciplines. In light of this, integrated science education is of utmost importance for science education graduates, as it serves as a focal point for development and should be maximized to its full potential.

Based on the observations of Integrated Science Education lectures at one of the universities in East Java, it is evident that inquiry-based learning is not being implemented. The knowledge-building process is only conducted through student presentations and discussions. Critical and creative thinking skills, which are the intended outcomes of the lectures, are not being cultivated for designing integrated science education instructional materials. The examination of student assignments between two cohorts indicates a high degree of similarity.

This condition is in line with the issue that in designing integrated science education, mastery of critical and creative thinking skills is required (Wan & Lee, 2022). This is highly beneficial for analyzing and synthesizing various content and pedagogy in integrated science education when aiming to achieve coherence across different branches of science (Fortus & Krajcik, 2012). This can have an

impact on the lack of competence in preparing integrated science education, including effectively delivering its content and pedagogy in the process of integrating various disciplines (Sun *et al*., 2014).

The reflection of integrated science learning issues can serve as a basis for further developing higher-order thinking skills such as critical and creative thinking. This is because critical thinking skills play a role in fostering deep understanding, predicting problems and their solutions, analyzing arguments and generating insights, seeking various sources as references for their findings, summarizing and evaluating their findings, writing observation reports, and explaining new knowledge (Arsy et al., 2020; Irawati & Idrus, 2020). Training critical thinking skills is essential for every individual as it strengthens self-protection and the ability to make wise decisions in everyday activities, not only in learning situations (Liliasari, 2009). This highlights the importance of critical thinking that goes beyond the realm of education. Likewise, in the effort to train creative thinking skills, as the ability to develop ideas and insights to acquire new and meaningful knowledge (Dilekçi & Karatay, 2023). Training creative thinking skills means training to be able to discover original ideas or outcomes, promoting evidence-based conclusions, facilitating associative thinking, sharing impressive ideas, and encouraging original perspectives that stimulate the originality of thought outcomes (Şener & Taş, 2017; K. K. Yang et al., 2016).

Based on the results of a meta-analysis on students' critical and creative thinking skills, both skills are highly important for students to possess. Critical and creative thinking skills, as part of higher-order thinking skills, are needed not only in learning but also in various aspects of life (Siburian et al., 2019). Therefore, it is important to understand the current status of prospective science teachers regarding their mastery of critical and creative thinking skills in the topic of energy and its integration. This serves as the objective of this research.

II. METHODS

This study is quantitative research that is described descriptively regarding the status of critical thinking skills and creative thinking skills of prospective science teacher in the topic of energy and its integration. This study utilized a survey method conducted at a university in East Java. It involved 76 prospective science teachers who were enrolled in the integrated science curriculum course as detailed in Table 1.

Table 1. Participants of Prospective Science Teachers

No.	Gender	f
1	Male	31
2	Female	45
	Total	76

The research instruments used were essay tests, observation sheets, and interview guidelines. The indicators of critical thinking skills used in this study were based on: 1)

elementary clarification, 2) basic support, 3) inference, 4) advanced clarification, and 5) strategy and tactics. (Ennis, 1985). The indicators of creative thinking skills used in this study were based on: 1) fluency, 2) flexibility, 3) originality, and 4) elaboration (Guilford, 1975). The data obtained were then analyzed descriptively to determine the profile of students' critical and creative thinking skills. The results obtained will be categorized into five sections as shown in Table 2. The critical thinking and creative thinking tests were developed based on the topic of energy integrated with topics such as matter and its changes, heat, organization of living systems, ecosystems, environmental pollution, and global warming. There were 24 test items, consisting of 12 items for critical thinking skills and 12 items for creative thinking skills. The test duration was 120 minutes.

As for the data collection, it follows the steps outlined in flowchart Figure 1.

Figure 1. flowchart data collection

Based on Figure 1, the researcher engages in various activities to gather information that forms the basis for assessing the status of students' critical and creative thinking skills. In order to collect this information, the researcher combines various methods such as observation, literature review, and tests. Subsequently, the researcher analyzes the extent to which students have been equipped with critical and creative thinking skills. The researcher interprets the results of the tests of students' critical and creative thinking skills as the most recent outcomes.

Table 2. Categories of Critical and Creative Thinking Skills (Rahmawati et al., 2023)

Category	Score
Excellent (E)	81-100
Good (G)	61-80
Fair (F)	41-60
Poor (P)	21-40
Very Poor (VP)	0-21

III. RESULTS AND DISCUSSION

Based on the analysis of the students' critical thinking skills test, the results obtained are less satisfactory. The results indicate that only a small portion of the students achieved good scores or met the predetermined standard of critical thinking skills. Out of the five aspects of critical thinking skills, only a few students reached fair results, while the majority were categorized as less satisfactory or very unsatisfactory. Figure 1 presents the details of the five indicators of critical thinking skills that were tested.

Based on figure 2, it is found that in the indicator of elementary clarification, a total of 64% of students scored below the average, with 46% categorized as poor and 18% categorized as very poor. This condition suggests that students are not yet proficient in analyzing questions and simultaneously asking

and answering clarification questions. Their understanding of integrated science learning is still relatively low, which leads to their answers being less aligned with expectations. This is because the skills to focus questions through formulation and criteria, analyze arguments, and ask and answer questions effectively are important aspects of providing elementary clarification. (Ennis & Weir, 1985).

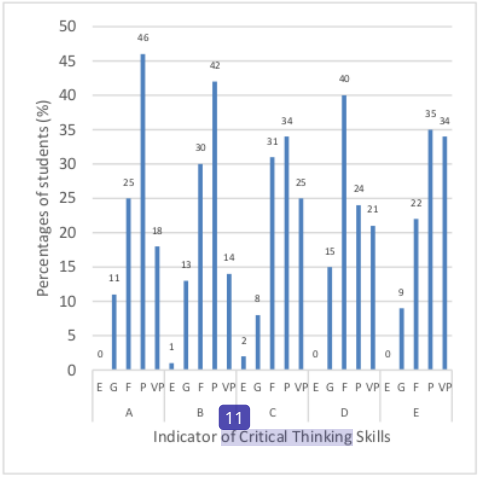

Figure 2. Percentage of Each Indicator of Critical Thinking Skills; A: elementary clarification, B: basic support, C: inference, D: advanced clarification, and E: strategy and tactics

Furthermore, the indicator of basic support skills also shows unsatisfactory results. The analysis reveals that 42% of students are categorized as poor, while 14% fall into the very poor category. Based on the analysis, it indicates that students lack the ability to assess source credibility and consider evaluation results from conducted tests. They face difficulties in determining valid sources for a given case, often assuming that the presented information is true based on their own logical reasoning. For example, students have not yet understood how to differentiate between trustworthy and unreliable sources, and they haven't grasped the importance of evaluating sources for accuracy and bias. Additionally, when faced with cases that require the skill of evaluating scientific test results, students struggle to describe them. If students understand the significance of source evaluation and possess the necessary skills, they would be better equipped to navigate information and utilize valid and trustworthy sources in their work (Carlson, 1995; D'Angelo, 2001; Ennis, 2015).

The indicator of inference also obtained unsatisfactory results. The percentage of students categorized as poor is 34%, while 25% fall into the very poor category. Students lack the ability to generate and determine sound conclusions by referring to background information and factual application. It is essential for students to learn how to effectively evaluate the background of a situation or problem. This skill is crucial for understanding and effectively applying facts through critical thinking activities (Duran & Dökme, 2016). Critical thinking involves knowledge of how to analyze information, question assumptions, and comprehend logic and arguments (Bezanilla et al., 2019). This is because in order to effectively apply facts, students must be able to understand

information, retain it, and apply it in new situations. This skill involves understanding how information is interconnected and how it can be used in problem-solving (Ma'ruf et al., 2020).

The same applies to the indicator of advanced clarification, where 24% of students are categorized as poor and 21% as very poor. The analysis shows that students have a limited understanding of identifying assumptions and analyzing the relevance of a given definition. Students face difficulties in constructing coherent arguments, effectively presenting information, and conveying their ideas clearly and persuasively. Enhancing students' understanding of assumptions and definitions can help them become more effective readers, writers, and researchers. It will also aid them in developing critical thinking skills that are vital for success in various fields and professions (Binkley et al., 2012; ŽivkoviĿ, 2016).

On the indicator of organizing strategies and tactics, 35% of students are categorized as poor, while 34% are categorized as very poor. Students face difficulties in determining appropriate actions for various criteria and presented problems, as well as considering suitable solutions. They lack sufficient understanding of how strategies and tactics work and how they can be utilized in problem-solving. This may involve understanding how to formulate goals, plan steps to achieve those goals, and adjust the plans based on the existing conditions. These difficulties indicate a lack of understanding of the problem-solving process itself or a lack of practical experience in applying that process. To effectively consider appropriate solutions and adjust strategies and tactics, students need to develop critical and analytical thinking skills (Hartini et al., 2022). The lack of mastery of critical thinking skills among students is a less favorable condition, considering the importance of these skills in integrated science education.

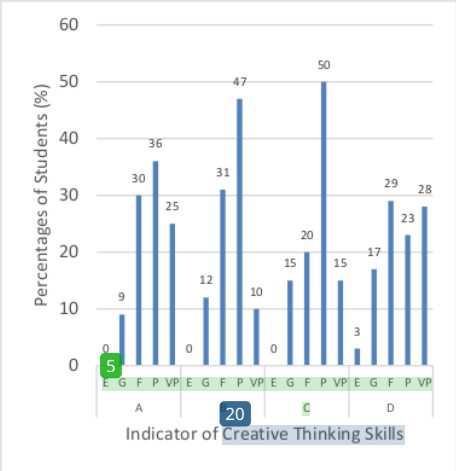

Figure 3. Percentage of each indicator of creative thinking skills; A: fluency, B: flexibility, C: originality, D: elaboration

According to Figure 3, the fluency indicator obtained unsatisfactory results. Approximately 36% of students were categorized as poor, and 25% fell into the very poor category.In this indicator, students demonstrate limitations in generating new alternatives or ideas. The lack of fluency may indicate difficulties in spontaneously

generating ideas or expressing thoughts smoothly. However, fluency in the context of creative thinking typically refers to the ability to produce a high quantity of ideas in a short period of time (Guilford, 1975; Suherman, 2022; Xu et al., 2022).

On the flexibility indicator, the percentage of students falling under the category of poor is 47%, while the percentage under the category of very poor is 10%. The analysis results indicate that students tend to be stuck in a single way of thinking or a single approach. They face challenges in adopting different perspectives or exploring innovative approaches. Flexibility, in the context of creative thinking, refers to the ability to think in diverse ways and generate a variety of ideas. It is important for students to be able to consider problems from multiple angles, enabling them to propose appropriate solutions (Gu et al., 2019; Gube & Lajoie, 2020). Students need to be able to view problems from multiple perspectives in order to propose suitable solutions (Mursid et al., 2022; Purwaningsih & Supriyono, 2020).

Furthermore, in the originality indicator, the percentage of students falling into the poor category is 50%, while the very poor category comprises 15% of the total students. Students tend to generate ideas that are cliché or conventional, lacking creativity or novelty. They struggle to think beyond existing boundaries or conventions. Originality, in the context of creative thinking, refers to the ability to generate unique, fresh, or unconventional ideas (X. Yang et al., 2022). This needs to be taken into consideration because if students are accustomed to thinking in conventional ways, they may find it challenging to think outside the box and produce new or different ideas.

In the elaboration indicator, the percentage of students falling into the poor category is 23%, while the very poor category comprises 28% of the total students. Students lack the ability to provide in-depth explanations or elaborate on ideas effectively. Elaboration, in the context of creative thinking, refers to the ability to expand or elaborate on ideas or concepts, provide details and context, and demonstrate a deep understanding (Yustina et al., 2022). Elaboration involves the ability to communicate ideas and concepts clearly and effectively for students.

The implications of this research describe the profile of achievement in critical thinking skills and creative thinking skills of prospective science teacher students, which can serve as a foundation for developing an integrated science education program. These findings also present an opportunity to develop software that aligns with current technological advancements to assist students in enhancing their critical thinking and creative thinking skills.

IV. CONCLUSION AND SUGGESTION

Based on the results and discussions, it is apparent that students have a less satisfactory

level of mastery in critical and creative thinking skills across all indicators. The shortcomings in their mastery of these skills highlight the need to enhance the teaching approach, particularly in foundational content areas that have strong integration with various topics, such as energy and its integration. The implementation of more effective instructional strategies to cultivate critical and creative thinking skills is crucial, as it will provide students with greater opportunities to practice and develop these skills. Furthermore, there are opportunities to introduce innovative scaffolding methods to facilitate the attainment of these skills.

Future researchers can conduct measurements of problem-solving skills and decision-making as part of higher-order thinking skills. Additionally, measuring various topics beyond the tests conducted can broaden the current status of students' critical thinking skills and creative thinking skills. Researchers are expected to assist students in continuously enhancing their higher-order thinking skills through various innovative lectures.

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