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

Kadek Dwi Hendratma Gunawan[1)*], Liliasari [2)], Ida Kaniawati [2)], Riandi[2)]

[1)]Department of Computerized Accounting, Politeknik Ganesha Guru, 81151, Indonesia
[2)]Department of Science Education, Universitas Pendidikan Indonesia, 40154, Indonesia

**Corresponding author: hendratmagunawankadek@upi.edu*

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Abstract – *Developing critical and creative thinking skills is essential for prospective science teachers to address complex scientific problems and design effective integrated science learning. This study aimed to evaluate the critical and creative thinking skills of prospective science teachers, particularly on energy and its integration with other scientific topics. A total of 76 prospective science teachers from a university in East Java, Indonesia, participated in the study. Data were collected using essay tests, observation sheets, and interviews, with critical thinking indicators based on the Ennis framework and creative thinking indicators based on the Guilford framework. The data were analyzed descriptively. The results indicated that students' critical and creative thinking skills were generally in the low category across most indicators. In critical thinking, difficulties were observed in areas such as inference, advanced clarification, and strategy formulation. Similarly, in creative thinking, low scores were evident in fluency, flexibility, originality, and elaboration indicators. These findings highlight the urgent need for instructional innovations and targeted interventions to enhance critical and creative thinking skills among prospective science teachers. Strengthening these skills is crucial for preparing future educators capable of designing and implementing effective integrated science learning strategies. Further research is recommended to explore instructional models and scaffolding techniques that can better support the development of these competencies across diverse scientific topic.*

Keywords: *creative thinking skills; critical thinking skills; energy; 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 to understand and interpret scientific phenomena encountered in daily life. The implementation of integrated science learning emphasizes the importance of a broad scientific foundation in primary and secondary education to understand natural sciences and address problems demanding interdisciplinary solutions (Lee & Wan, 2022). The integration of science learning can benefit students by fostering understanding, literacy, and 21st-century skills, among other advantages (Wallace & Coffey, 2019).

The implementation of Integrated Science learning lectures aims to equip students with conceptual and procedural competencies 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, students frequently encounter challenges while designing integrated science learning tools, including misunderstandings of content, integration misconceptions, diverse scientific backgrounds, and difficulties in assembling coherent materials (Gunawan et al., 2019; Indrawati & Nurpatri, 2022; Rubini et al., 2019; Sun et al., 2014; Wei, 2020). Additionally, certain topics, like energy and its interdisciplinary integrations, remain challenging to comprehend (Gunawan et al., 2019).

The challenges in the field emphasize the need for science educators to have a comprehensive grasp of unified knowledge. This enhances learning activities and supports interpreting everyday phenomena through multiple 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 enables integrated science learning to unify its sub-disciplines effectively. In light of this, integrated science education is of utmost importance for science education graduates, serving as a critical area for development and maximization.

Based observations of Integrated Science Education lectures at a university in East Java, inquiry-based learning is notably absent. The knowledge-building process relies solely on student presentations and discussions. Critical and creative thinking skills, intended as lecture outcomes, are not being developed for creating integrated science instructional materials. The examination of student assignments between two cohorts indicates a high degree of similarity.

This condition aligns with the necessity for mastering critical and creative thinking skills in designing integrated science education (Wan & Lee, 2022). This facilitates the analysis and synthesis of content and pedagogy, achieving coherence across scientific disciplines (Fortus & Krajcik, 2012). This can result in deficiencies in competence for preparing integrated science education, including effective content delivery and pedagogy integration (Sun et al., 2014).

The reflection of integrated science learning issues serves as a foundation for advancing higher-order thinking skills like critical and creative thinking. This is due to critical thinking's role in fostering deep understanding, predicting problems, analyzing arguments, generating insights, using diverse references, summarizing findings, and presenting new knowledge (Arsy et al., 2020; Irawati & Idrus, 2020). Training critical thinking skills strengthens individuals' decision-making and problem-solving abilities in everyday and learning contexts (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, creative thinking involves developing original ideas and insights (Dilekçi & Karatay, 2023). Training creative thinking skills encourages generating original ideas, evidence-based conclusions, associative thinking, and innovative perspectives (Şener & Taş, 2017; Yang et al., 2016).

Based on the results of a meta-analysis on students' critical and creative thinking skills, these skills are critical for students. Critical and creative thinking skills, as part of higher-order thinking skills, are vital in learning and diverse life contexts (Siburian et al., 2019). Therefore, evaluating the current status of prospective science teachers' mastery of these skills, particularly in energy-related topics, is essential. This forms the objective of this study.

II. METHODS

This study was quantitative research using a descriptive approach to analyze the status of prospective science teachers' critical and creative thinking skills concerning energy and its integration topics. 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 shown in Table 1.

Table 1. Participants of prospective science teachers

No.	Gender	Frequency
1	Male	31
2	Female	45
	Total	**76**

The research instruments used included essay tests, observation sheets, and structured interview guidelines. The indicators of critical thinking skills used in this study followed the framework of: 1) elementary clarification, 2) basic support, 3) inference, 4) advanced clarification, and 5) strategy and tactics (Ennis, 1985). The indicators of creative thinking skills were derived from: 1) fluency, 2) flexibility, 3) originality, and 4) elaboration (Guilford, 1975). The data obtained underwent descriptive analysis to profile the students' skills in both areas. The results obtained were categorized into five levels, as outlined in Table 2. The critical thinking and creative thinking tests were designed around the energy topic, integrating related themes such as matter and its changes, heat, 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. Each test was administered over 120 minutes.

As for data collection, the process is illustrated in Figure 1.

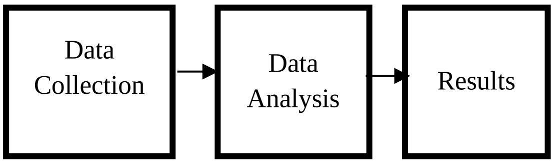

Figure 1. Flowchart of the data collection process

Based on Figure 1, the researcher engages in various activities to gather information to assess the students' critical and creative thinking skills comprehensively. In order to collect this information, the employed multiple methods, including observation, literature review, and testing. Subsequently, the researcher analyzed the extent of students' preparedness in critical and creative thinking skills. The researcher interpreted the test results to provide insights into the current status of these skills.

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 were less than 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. The performance across the five tested indicators is detailed in Figure 2.

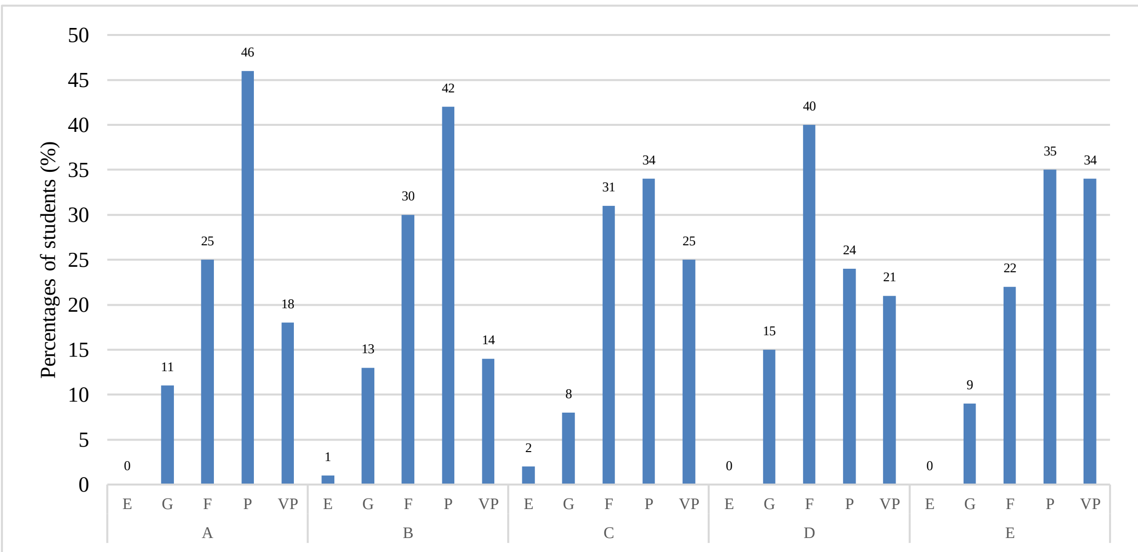

Figure 2. Percentage of each indicator of critical thinking skills; A: elementary clarification, B: basic support, C: inference, D: advanced clarification, and E: strategy and tactics

Based on figure 2, 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. The skills required to focus questions based on formulation and criteria, analyze arguments, and ask and answer questions effectively are crucial for elementary clarification (Ennis & Weir, 1985).

Furthermore, the indicator of basic support skills also yielded poor results. The analysis reveals that 42% of students are categorized as poor, while 14% fall into the very poor category. This suggests that students struggle to assess source credibility and evaluate test results effectively. 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 do not fully understand how to differentiate between trustworthy and unreliable sources, and they fail to recognize the importance of evaluating sources for accuracy and bias. Additionally, when faced with tasks requiring the evaluation of scientific test results, students face challenges in articulating their analysis. If students were equipped with source evaluation skills, they would navigate information more effectively and utilize valid sources in their work (Carlson, 1995; D'Angelo, 2001; Ennis, 2015).

The indicator of inference also showed concerning results. The percentage of students categorized as poor is 34%, while 25% fall into the very poor category. Students lack the ability to draw logical conclusions based on background information and factual evidence. It is essential for students be trained to evaluate the background of a situation or problem effectively. This skill is crucial for understanding and effectively applying facts through critical thinking activities (Duran & Dökme, 2016). Critical thinking involves the ability to analyze information, question assumptions, and comprehend logical arguments (Bezanilla et al., 2019). To apply facts effectively, students must understand, retain, and adapt information to new situations. This skill involves recognizing the interconnectedness of information and utilizing it 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 in a clear and persuasive manner. Enhancing students' understanding of assumptions and definitions would improve their effectiveness as readers, writers, and researchers. It will also aid them in developing critical thinking skills that are essential for success across disciplines (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 situations and problems, and in identifying 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 set goals, plan steps, and adapt those plans based on conditions. These difficulties suggest a limited understanding of the problem-solving process or insufficient practical experience. To effectively apply strategies and tactics, students must develop critical and analytical thinking skills (Hartini et al., 2022). This deficiency is concerning given the importance of these skills in integrated science education.

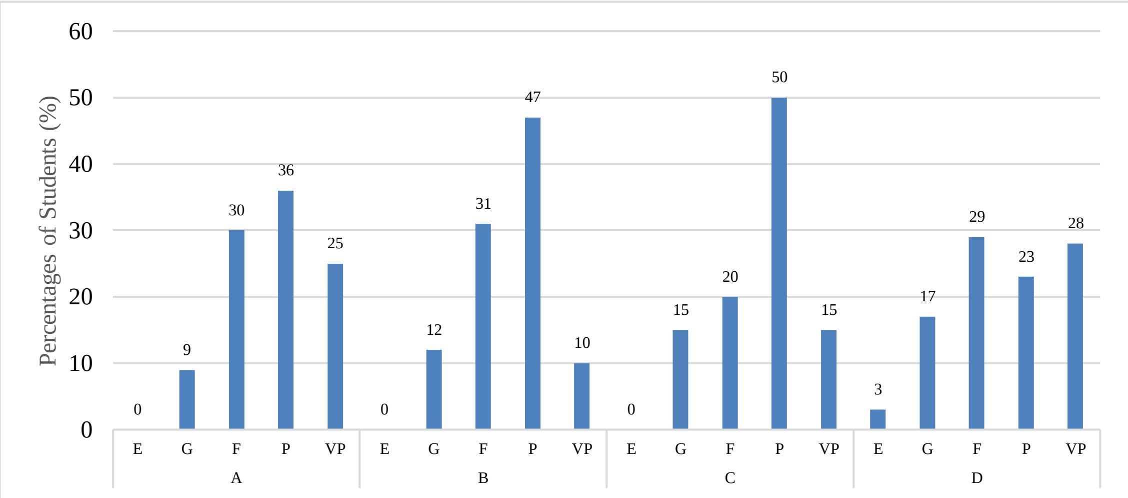

Figure 3. Percentage of each indicator of creative thinking skills; A: fluency, B: flexibility, C: originality, D: elaboration

According to Figure 3, the fluency indicator revealed poor performance. 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 ideas and alternatives. The lack of fluency may reflect difficulties in generating spontaneous ideas or expressing thoughts fluidly. However, fluency in the context of creative thinking typically refers to producing a large number of ideas efficiently (Guilford, 1975; Suherman & Vidakovich, 2022; Xu et al., 2022).

The flexibility indicator revealed that 47% of students fall into the poor category, while 10% are categorized as very poor. The analysis suggests that students often rely on rigid thinking patterns or a single approach. They face challenges in adopting different perspectives or exploring innovative approaches. Flexibility, in the context of creative thinking, is defined as the ability to generate diverse ideas and consider problems from multiple angles. It is important for students to adopt varied perspectives to propose appropriate solutions (Gu et al., 2019; Gube & Lajoie, 2020). Developing this skill allows students to tackle problems effectively from different viewpoints (Mursid et al., 2022; Purwaningsih & Supriyono, 2020).

Furthermore, in the originality indicator, 50% of students fall into the poor category, while 15% are categorized as very poor. Students tend to generate ideas that are conventional and lack originality or novelty. They find it challenging to think outside existing frameworks or conventions. Originality, in the context of creative thinking, is defined as the capacity to produce unique, fresh, and unconventional ideas (Yang et al., 2022). If students remain accustomed to conventional thinking, they may struggle to generate innovative or unconventional ideas.

In the elaboration indicator, 23% of students fall into the poor category, while 28% are categorized as very poor. Students lack the ability to offer detailed explanations or expand on their ideas effectively. Elaboration, in the context of creative thinking is defined as the capacity to expand on concepts, add relevant details, and demonstrate comprehensive understanding (Yustina et al., 2022). It also requires students to communicate their ideas with clarity and precision.

The findings of this research provide an overview of prospective science teachers' achievements in critical and creative thinking skills, forming a foundation for developing integrated science education programs. These findings highlight opportunities for developing software tools aligned with current technological advancements to support students in improving their critical and creative thinking skills.

IV. CONCLUSION AND SUGGESTION

Based on the results and discussion, it is evident that students demonstrate an unsatisfactory level of mastery in critical and creative thinking skills across all assessed indicators. The shortcomings in their mastery of these skills underscore the necessity of improving teaching approaches, especially in foundational content areas that integrate multiple topics, such as energy and its applications. The implementation of more effective instructional strategies to foster critical and creative thinking skills is essential, as it will create better opportunities for students to practice and refine these skills. Furthermore, there are opportunities to explore innovative scaffolding techniques to support students in achieving these skills effectively.

Future researchers can explore problem-solving and decision-making skills as key components of higher-order thinking skills. Additionally, investigating diverse topics beyond the current assessments can provide a more comprehensive understanding of students' critical and creative thinking abilities. Researchers are encouraged to support students in consistently improving their higher-order thinking skills through innovative teaching methods and approaches.

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