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Analyzing Students' Creative Thinking Skills as a Basis for Developing Digital Physics Teaching Materials on Renewable Energy Topics

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Abstract – *The rapid advancement of digital technology demands creative, contextual, and sustainability-aligned physics learning. However, high school physics instruction, particularly on renewable energy topics, remains largely conventional and relies on static media, limiting students' opportunities to develop creative thinking skills. This study aimed to analyze students' creative thinking skills and learning needs, providing an empirical foundation for the development of contextual, interactive digital physics teaching materials on renewable energy. A descriptive quantitative research design was employed, supported by qualitative data from the teachers' interviews. The participants consisted of 266 tenth-grade students and three physics teachers from three public senior high schools in Tebo Regency, Indonesia. Data were collected using a 32-item learning-needs questionnaire, a creative thinking skills test based on fluency, flexibility, originality, and elaboration indicators, and semi-structured interviews with teachers. Quantitative data were analyzed using descriptive statistics, and qualitative data were examined through thematic analysis. The results indicate that teacher-centered practices, with limited use of interactive digital media, still dominate physics instruction. Students demonstrated a high demand for contextual, problem-based, and digital learning environments, with an overall learning needs mean score of 82.5%. However, students' creative thinking skills were generally low, with an average score of 41.8%, particularly in fluency, flexibility, and originality, while elaboration emerged as the relatively strongest indicator. The novelty of this study lies in integrating students' creative thinking profiles with their learning needs and classroom practices to provide an empirical basis for the instructional design. The findings indicate a significant gap between students' learning needs and current instructional practices, underscoring the need to develop contextual, interactive digital physics teaching materials. This study contributes to physics education by offering diagnostic evidence to guide the design of digital learning innovations that foster creative thinking and sustainability-oriented understanding.*

Keywords: *creative thinking skills; digital teaching materials; renewable energy; contextual physics learning; secondary school*

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I. INTRODUCTION

The rapid advancement of digital technology has fundamentally reshaped educational practices, compelling a shift from conventional instruction toward learning environments that emphasize creativity, contextual relevance, and higher-order thinking. In physics education, however, instructional practices in many secondary schools remain predominantly teacher-centered, relying heavily on lectures and static media such as textbooks or slide presentations (Batlolona & Diantoro, 2023; Sihombing et al., 2025). These approaches often position students as passive recipients of information, limiting opportunities for exploration, idea generation, and creative reasoning. This gap between technological advancement and classroom practice presents a critical challenge for physics education in preparing students to meet the demands of twenty-first-century learning. Previous studies have demonstrated that the integration of interactive media in physics learning can strengthen students' digital skills and active engagement; however, such approaches have not yet been consistently implemented in everyday classroom practices (Nurazmi et al., 2025).

The challenge becomes particularly evident in the teaching of renewable energy topics. Renewable energy concepts inherently require contextual understanding, systems thinking, and the ability to relate abstract physical principles to real-world sustainability issues. Nevertheless, these topics are often delivered in an abstract, formula-driven manner, detached from students' daily experiences (Melur et al., 2025; Pinar et al., 2025). As a result, students often struggle to construct meaningful understanding and demonstrate limited creative engagement with the content. Addressing this issue requires not only pedagogical innovation but also a clear understanding of students' cognitive readiness and learning needs.

Creative thinking is widely recognized as a core competence in contemporary science and physics education. It enables learners to generate multiple ideas, explore alternative solution pathways, and design innovative responses to complex problems (Pinar et al., 2025). In the context of physics learning, creative thinking supports deeper conceptual understanding by encouraging students to move beyond algorithmic problem-solving toward flexible, original reasoning (Batlolona & Diantoro, 2023). Despite its importance, numerous studies in Indonesia have consistently reported that students' creative thinking skills remain at low to moderate levels, particularly in the dimensions of originality and elaboration (Ena et al., 2025; Melur et al., 2025). These findings suggest that existing instructional practices have not yet provided sufficient learning conditions to nurture scientific creativity.

In this study, creative thinking is operationally defined through four key indicators: fluency, flexibility, originality, and elaboration (Khalil et al., 2023). Fluency refers to the ability to generate multiple ideas; flexibility to the ability to shift between different perspectives or strategies; originality to the capacity to produce novel or uncommon ideas; and elaboration to the ability to develop and refine ideas in detail. These indicators are particularly relevant in renewable energy learning, where students are required to analyze energy conversion processes, compare alternative technologies, propose sustainable solutions, and interpret contextual phenomena. Renewable energy topics often involve open-ended and design-oriented problem spaces, making creative thinking an essential cognitive foundation for meaningful learning.

Recent developments in digital pedagogy offer promising opportunities to address these challenges. Digital learning materials that integrate interactivity, visualization, and contextual problem solving have been shown to enhance student engagement, motivation, and conceptual understanding in physics (Aiyesi et al., 2025; Firdaus et al., 2025). In renewable energy education, digital media can facilitate visualization of abstract processes, such as energy transformation and system efficiency, while simultaneously fostering environmental awareness and sustainability-oriented literacy (Badiah et al., 2024; Rizki et al., 2024). However, the effectiveness of digital innovation depends on its alignment with students' learning needs and cognitive profiles, rather than mere technological adoption.

Before developing digital-based instructional materials, it is therefore essential to conduct a preliminary analysis of existing classroom conditions. Understanding how physics is currently taught, which learning resources are used, and how students engage with renewable energy topics provides critical empirical grounding for instructional design (Sapulete et al., 2023). Moreover, identifying students' creative thinking profiles and learning preferences allows educators to design materials that are pedagogically relevant and cognitively appropriate. A descriptive quantitative approach, complemented by qualitative insights from teachers, enables a systematic exploration of these factors within authentic school contexts (Rizki et al., 2024; Wijayanto et al., 2023).

This study focuses on three interrelated dimensions. The first concerns teachers' perspectives on physics teaching practices, particularly the use of instructional media and strategies in renewable energy learning. Teachers' insights are crucial for understanding practical constraints, pedagogical tendencies, and instructional challenges faced in real classrooms. The second-dimension addresses students' learning needs, including their preferences for learning styles, media, and contextual relevance. Learning needs analysis provides evidence of students' readiness to engage in digital and creative learning environments. The third dimension examines students' creative thinking skills across the indicators of fluency, flexibility, originality, and elaboration (Patriot et al., 2025; Siyamuningsih et al., 2025). Integrating these dimensions enables a comprehensive diagnosis of the learning environment and its potential for creative, digital-based instruction.

Previous empirical studies have demonstrated that contextual, project-based, and digitalized learning models can significantly enhance students' creative thinking compared to conventional approaches (Wijayanto et al., 2023). Digital simulations and virtual laboratories allow learners to manipulate variables, visualize phenomena, and explore multiple solution pathways, thereby supporting divergent and reflective thinking (Patriot et al., 2025; Siyamuningsih et al., 2025). In renewable energy learning, contextual digital materials have been shown to strengthen students' originality and flexibility by linking physics concepts to sustainability challenges relevant to their daily lives (Badiah et al., 2024). These findings underscore the pedagogical potential of digital materials when they are intentionally designed to foster creativity.

Despite growing evidence of the benefits of digital and contextual learning, many schools continue to implement technology in a limited and fragmented manner. Digital tools are often used merely as presentation media rather than as platforms for inquiry, exploration, and creative problem solving. This misalignment highlights the need for a more principled approach to instructional design, grounded in empirical analysis of students' cognitive characteristics and learning needs. Without such analysis, digital innovations risk replicating traditional teacher-centered practices in a digital format, rather than transforming learning experiences.

Based on these considerations, this study aims to analyze current conditions in physics learning on renewable energy topics, students' learning needs, and their creative thinking profiles, as an empirical foundation for developing contextual and interactive digital teaching materials. The novelty of this study lies in integrating the analysis of students' creative thinking profiles and learning needs to construct an empirical foundation for developing contextual and digital-based physics teaching materials on renewable energy topics. Unlike previous studies that primarily measured creative thinking levels, this research connects cognitive profiles with pedagogical design needs, providing a new perspective for developing innovative digital learning strategies in physics education. Therefore, this research seeks to answer three guiding questions: (1) What is the existing state of physics instruction on renewable energy topics from teachers' and students' perspectives? (2) What are students' learning needs in terms of media, learning styles, and interests? and (3) How are students' creative thinking skills distributed across fluency, flexibility, originality, and elaboration indicators?

II. METHODS

This study employed a descriptive quantitative research design supported by qualitative data from teacher interviews. The selection of this approach was intended to provide a comprehensive description of the existing conditions of physics learning, students' learning needs, and their creative thinking skills within authentic classroom contexts (Andarwulan et al., 2021; Loeb et al., 2017). The descriptive quantitative method was considered appropriate because it allows systematic observation and numerical description of educational phenomena while maintaining contextual interpretation through qualitative triangulation (Djafar et al., 2021). The integration of these two approaches strengthened the credibility of the findings by combining numerical trends with explanatory insights from practitioners.

The research was conducted during the 2024/2025 academic year, over a four-week period, in three public senior high schools in Tebo Regency, Indonesia. The schools were purposively selected to represent variations in accreditation level and geographical context, including urban, district, and suburban areas, in order to reflect diverse learning environments and infrastructure conditions (Siripipatthanakul et al., 2023). The participants consisted of 266 tenth-grade students enrolled in physics courses and three physics teachers who were actively teaching renewable energy topics. The distribution of student participants across schools is presented in Table 1, which illustrates the proportional representation of each school type and accreditation level.

Table 1. Distribution of research participants

School	Accreditation level	School type	Number of students
SHS A	High	City area	108
SHS B	Medium	District area	50
SHS C	Low	Suburban area	108
Total			266

The research instrument consisted of three main components designed to collect quantitative and qualitative data. The first instrument was a student learning-needs questionnaire consisting of 32 statements distributed across nine aspects: goals and aspirations, interests and enjoyment, self-efficacy, learning environment, problem-based learning activities, deep-learning processes, teaching materials, contextual materials, and creative thinking. Each item was assessed using a four-level Likert scale ranging from strongly disagree (1) to strongly agree (4). Each aspect consisted of 2-4 items aligned with its key indicators. Goals and aspirations measured students' academic goals and mastery orientation; interests and enjoyment captured curiosity and engagement; self-efficacy assessed confidence in solving physics problems; and the learning environment reflected teacher and peer support. Problem-based learning items addressed motivation toward real-world problems, while deep learning processes measured reflection and meaningful understanding. Teaching materials focused on clarity and structural support, contextual materials examined the relevance of renewable energy examples, and creative thinking assessed fluency, flexibility, originality, and elaboration.

The second instrument was a creative thinking skills test consisting of four open-ended essay items, each aligned with one of the four creative thinking indicators: fluency, flexibility, originality, and elaboration (Firdaus et al., 2025; Khalil et al., 2023). These indicators were selected due to their relevance in assessing students' ability to generate ideas, shift problem-solving strategies, produce novel solutions, and elaborate on conceptual reasoning, particularly in renewable energy contexts. To enhance methodological clarity, sample items included tasks such as proposing multiple strategies for reducing household electricity consumption and designing a unique improvement for a solar-powered device. These tasks were intentionally open-ended to elicit divergent and creative responses rather than algorithmic solutions.

All research instruments underwent expert validation by two specialists in physics education and language education to ensure content validity and linguistic clarity. The reliability of the learning-needs questionnaire was assessed using Cronbach's Alpha, yielding a coefficient of $\alpha = 0.87$, which indicates high internal consistency and acceptable reliability for educational research (Loeb et al., 2017). To reduce subjectivity in scoring the creative thinking test, an analytic scoring rubric adapted from prior creative thinking assessments was applied. Each indicator was scored on a scale from 0 to 4, ranging from no response to highly relevant and well-developed creative ideas. Student responses were independently scored by two trained raters, and discrepancies were resolved through discussion to ensure inter-rater consistency.

The research procedure was implemented through three sequential stages, as illustrated in Figure 1. The preparation stage involved coordinating with schools, validating instruments, and obtaining ethical approval. The implementation stage included administering the learning-needs questionnaire and creative thinking test to students under teacher supervision, as well as conducting teacher interviews. The final stage consisted of data processing and analysis.

Figure 1. Research procedure in this study

All quantitative data were processed using descriptive statistics to obtain percentage scores and mean values. The percentage of each student's creative thinking score was calculated using the following formula adapted from (Loeb et al., 2017).

$$S = \frac{R}{N} \times 100\%$$

Where:

S = Percentage of creative thinking skills

R = Total score obtained by the student

N = Maximum test score

The obtained values were then categorized according to the criteria shown in Table 2 to interpret the overall creative thinking ability of students.

Table 2. Classification of creative thinking skills based on percentage scores

No	Interval (%)	Category
1	86 - 100	Very high
2	76 - 86	High
3	60 - 75	Medium
4	55 - 59	Low
5	≤54	Very low

These classification categories were adapted and modified from prior studies on creative thinking assessment in physics education (Batlolona et al., 2019; Farschtschian, 2012). The results of each indicator were analyzed descriptively to reveal profiles of students' creative thinking. In contrast, the data from teacher interviews were analyzed qualitatively using thematic analysis that involved reduction, categorization, and interpretation based on framework. The integration of these two forms of data ensured the accuracy and credibility of findings through source triangulation

Throughout the research process, ethical principles were strictly maintained. All participants signed informed consent forms, and confidentiality of responses was ensured. The validity of the findings was reinforced through expert validation, data triangulation, and cross-checking across schools. This combination of methodological rigor and ethical compliance guaranteed that the data accurately represented the real conditions of physics learning and students' creative thinking skills in senior high schools (Djafar et al., 2021; Getliffe, 2008; Loeb et al., 2017). The chosen methodological structure provided a reliable empirical basis for the next stage of the research, which focuses on developing contextual and interactive digital teaching materials on renewable energy to enhance creative thinking in physics learning.

III. RESULTS

Interviews with three physics teachers teaching tenth-grade classes across three public senior high schools in Tebo Regency revealed that classroom instruction remained dominated by conventional, teacher-centered practices. The teachers primarily relied on textbooks, PowerPoint slides, and static videos, with limited implementation of experimental or inquiry-based activities. These practices restricted students' opportunities to explore and generate creative ideas. Although teachers acknowledged the practicality of these methods, they admitted that such approaches failed to stimulate students' curiosity and imagination. Teachers also highlighted that renewable energy topics were among the most difficult to teach due to their abstract nature and lack of direct visualization. One teacher noted, *students only see solar cells in pictures; they never explore how sunlight becomes electricity*. Teachers further observed that their students often demonstrated algorithmic rather than divergent problem-solving tendencies, as students tended to wait for sample problems and rarely attempted alternative approaches.

The analysis of students' learning needs provided empirical evidence related to these instructional conditions. The survey of 266 tenth-grade students revealed strong preferences for contextual and creative learning environments. As illustrated in Figure 2, the three highest indicators were contextual material (64%), problem-based activity (65%), and creative thinking development (63%). Although the percentage values for each aspect ranged from 63% to 65%, these indicators represent specific dimensions of learning needs rather than a cumulative score. The overall mean learning needs score of 82.5% was derived from aggregated responses across all assessed aspects, indicating a generally high level of learning demand. Furthermore, 62% of respondents preferred digital and interactive media. Students also demonstrated moderate to high levels of interest in deep learning (61%) and self-efficacy (60%). In addition, collaborative and autonomous learning environments were perceived as motivating, with percentage values ranging from 60% to 62%.

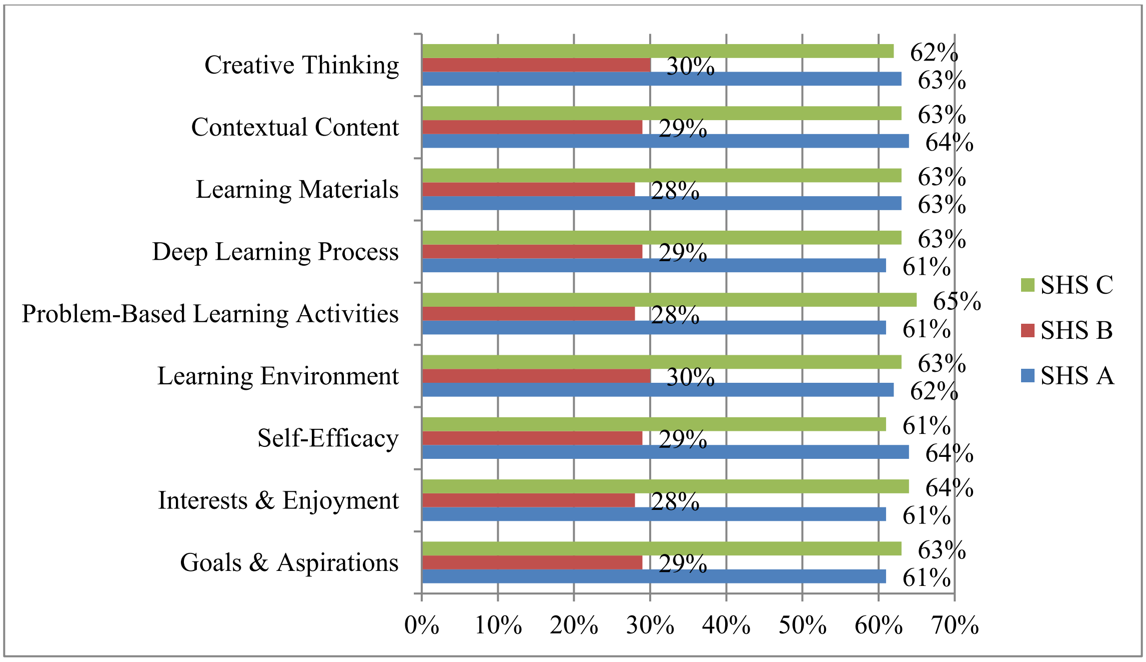

Figure 2. Students' learning needs in physics

The creative thinking test administered to 266 students revealed an overall average score of 41.8%, which was categorized as low. As shown in Figure 3, students achieved mean scores of fluency = 25.0%, flexibility = 25.3%, originality = 26.7%, and elaboration = 36.3%. This pattern was consistent across the three participating schools, although slight variations were observed. Students from SHS A demonstrated slightly higher flexibility (27%) and elaboration (39%), while SHS B recorded the lowest fluency score (23%). These results indicate that students were more capable of elaborating on given ideas than generating multiple ideas or adopting alternative solution strategies.

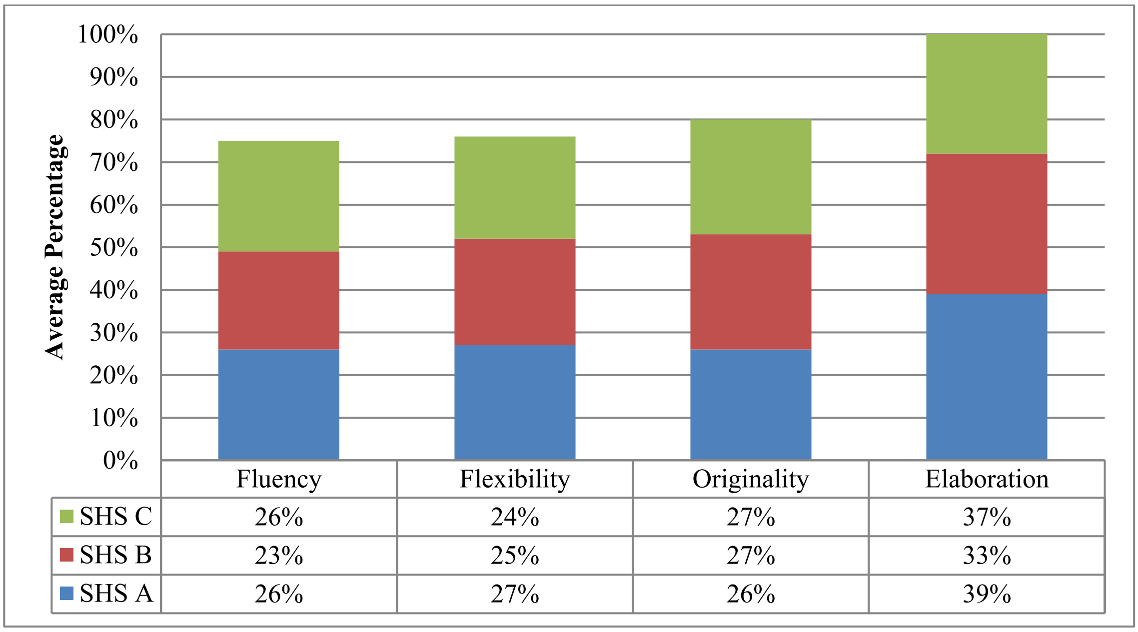

Figure 3. Students' creative thinking scores

IV. DISCUSSION

The dominance of conventional, teacher-centered instruction identified in this study aligns with previous reports indicating that limited use of varied instructional media negatively impacts students' cognitive and creative development. The challenges described by teachers reflect typical conditions in Indonesian physics classrooms, where abstract concepts remain disconnected from students' daily lives, resulting in weak conceptual understanding and low creativity. This finding is consistent with studies by Asrizal et al. (2023) and Gunawan et al. (2024), which reported that teacher-centered instruction limits students' exploratory learning in science classes. Unlike prior studies conducted in urban settings, the present research demonstrates that similar instructional patterns persist in semi-rural contexts, indicating a broader pedagogical issue that transcends geographic and institutional boundaries.

Teachers emphasized that contextual and digital learning tools are urgently needed to address these challenges. They believed that integrating renewable energy phenomena through interactive simulations or local problem contexts could help students connect theory to practice and enhance creative reasoning. This perception aligns with previous studies that demonstrate that contextual learning combined with digital visualization strengthens both scientific literacy and creativity (Prihata et al., 2020; Rizal et al., 2024). However, limited technical skills, insufficient internet access, and a lack of training constrained teachers' use of digital media. Similar conditions were reported by Hanč et al. (2024), who found that teachers' technological readiness significantly affects students' engagement and creative participation in science classes. Despite these constraints, teachers acknowledged the strong potential of digital simulations for topics requiring high visualization, such as energy transformation.

The tendency of students to rely on algorithmic problem-solving rather than divergent thinking further reflects an instructional emphasis on procedural mastery rather than idea generation. This condition mirrors previous findings showing that limited inquiry exposure restricts flexibility and originality in students' creative thinking (Hanč et al., 2024). Teachers' proposals for digital teaching materials that integrate authentic renewable energy problems, local contexts, and interactive challenges align with digital education frameworks that emphasize creativity, sustainability, and technology.

The strong student demand for contextual and problem-based learning supports the urgency of such pedagogical transformation. Prior studies have shown that contextualized and problem-based instruction increases engagement, motivation, and conceptual understanding (Asrizal et al., 2023; Rizki et al., 2024; Sundari et al., 2024). Students' preference for digital and interactive media further indicates readiness for technology-enhanced learning environments (Riswanto et al., 2025). Similar findings by Al-Kamzari and Alias (2024) and Maslakhah et al. (2024) confirm that digital media integration enhances curiosity and elaborative thinking, both of which are essential components of creativity. Moderate to high interest in deep learning and self-efficacy suggests that students are willing to engage in reflective and analytical processes. As noted by Kapanadze et al. (2023) and Sihombing et al. (2025), guided analytical and metacognitive activities can substantially improve flexibility and originality. Preferences for collaborative and autonomous learning environments further support the role of digital inquiry in fostering co-construction of knowledge and divergent perspectives (Jugembayeva & Murzagaliyeva, 2023; Prihata et al., 2020).

The low creative thinking performance observed in this study, particularly in fluency and flexibility, indicates limited opportunities for exploring alternative solution paths. Previous studies on project-based and STEM-oriented learning approaches reported significant improvements in these indicators when students were exposed to open-ended problem cycles (Patriot et al., 2025; Putra et al., 2025). Originality, the weakest indicator, requires instructional designs that encourage design-based experimentation and prototype development (Marlina et al., 2024; Rizki et al., 2024). Although elaboration emerged as the strongest indicator, its moderate level suggests that students tend to expand on known examples rather than develop novel extensions. Kwon and Lee (2025) emphasized that reflective feedback and iterative project cycles are crucial for transforming elaboration into innovation.

Comparative analysis with previous research confirms that the creative thinking profiles identified in this study are representative of broader patterns in Indonesian physics education (Melur et al., 2025; Ena et al., 2025). However, the present study contributes a distinctive perspective by integrating quantitative diagnostics with qualitative teacher insights, providing a more holistic understanding of classroom conditions. This triangulated approach provides a stronger empirical basis for material development than studies that rely solely on test data. The findings reaffirm that digital-based, contextual physics materials are essential resources for enhancing students' creative engagement with science concepts (Wijayanto et al., 2023). Consequently, combining creative thinking assessment with learning-needs analysis provides a comprehensive framework for designing digital teaching materials that foster creativity and sustainability awareness in physics education.

V. CONCLUSION AND SUGGESTION

This study investigated current conditions in physics learning on renewable energy topics, students' learning needs, and their creative thinking skills, providing an empirical foundation for the development of digital physics teaching materials. The findings indicate that physics instruction in the observed schools remains largely conventional and relies on static media, which provides limited opportunities for creative exploration. At the same time, students demonstrated a high demand for contextual, problem-based, and digital learning environments. Despite this readiness, students' creative thinking skills were generally low, particularly in fluency, flexibility, and originality, while elaboration emerged as the relatively strongest indicator. These results collectively reveal a clear gap between students' learning needs and existing instructional practices, underscoring the need for contextual, interactive digital teaching materials that explicitly support the development of creative thinking in renewable energy learning.

Although this study offers valuable diagnostic insights, several limitations should be acknowledged. The research employed a descriptive design and was conducted in a limited regional context, which may restrict the generalizability of the findings to other educational settings. In addition, the study did not examine the effectiveness of specific digital teaching materials in improving students' creative thinking outcomes. Future research is therefore recommended to focus on the design, implementation, and experimental evaluation of contextual digital learning modules, such as problem-based or project-based e-worksheets, that integrate renewable energy issues with creative thinking frameworks. Further studies should also explore the role of teacher professional development in supporting the effective use of digital and creativity-oriented instruction. Despite these limitations, this study contributes to the field of physics education by providing an integrative empirical analysis that links students' creative thinking profiles, learning needs, and classroom practices. This contribution provides a robust foundation for developing digital instructional innovations that foster creativity, contextual understanding, and sustainability awareness in physics learning.

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