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From Development to Impact: A Guided-Inquiry and Blended Learning Electricity-Magnetism Module to Foster Pre-Service Physics Teachers' Scientific Creativity

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Abstract

In the era of technological advancement and modern education, delivering effective and innovative physics instruction is essential. A critical aspect in teaching electricity and magnetism is the provision of learning materials that integrate guided inquiry and blended learning approaches to create more interactive, in-depth, and relevant experiences for learners. This study aimed to develop a three-chapter guided-inquiry and blended learning module on electricity–magnetism to foster pre-service physics teachers' scientific creativity. Using a 4D model (define, design, develop, and disseminate), the research was conducted over six months. The module was first designed and validated by experts in content, pedagogy, language, and technical aspects, followed by limited-scale trials to refine its quality. Furthermore, a large-scale implementation was carried out to evaluate the effectiveness of the developed teaching materials on each sub-indicator of scientific creativity. The large-scale implementation employed a quasi-experimental method with third-semester students of the Physics Education Study Program at the University of Mataram as the sample. Using a pre-test–post-test control group design, the data obtained indicated a significant difference between the two groups. In addition, the research findings revealed that the developed teaching materials demonstrated a high level of validity across all assessment aspects. Based on the N-gain analysis in the large-scale testing phase, the results indicated that the teaching materials significantly enhanced the scientific creativity of prospective physics teachers, particularly in the aspect of Scientific Knowledge within the Thinking component, with a score of 65% in the medium category, and in Flexibility with a score of 60%. It is concluded that the guided-inquiry and blended learning electricity–magnetism module is valid and effective in fostering scientific creativity and can serve as a model for innovative physics instruction in teacher education programs.

Keywords: Electricity–magnetism module; Guided inquiry; Blended learning; Scientific creativity; Pre-service physics teachers

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INTRODUCTION

The development of inquiry-based physics teaching materials has been shown to enhance students' critical thinking skills (Herawati & Setiawan, 2020). This approach aligns with the view that effective instruction should emphasize active student engagement in discovering concepts (Driscoll, 2019). Therefore, developing teaching materials that integrate guided-inquiry strategies is essential for pre-service physics teachers. The electricity–magnetism module developed through this approach is expected to foster students' scientific creativity. Consequently, this study focuses on developing guided-inquiry-based electricity–magnetism teaching materials.

Previous research has reported that the development of inquiry-based physics teaching materials can substantially enhance students' critical thinking performance. For example, Herawati and Setiawan (2020) found that students who learned through inquiry-oriented modules achieved a 32% higher post-test score compared to those in conventional classrooms, particularly in analyzing and evaluating indicators of critical thinking. This evidence supports the claim that instruction which requires students to actively observe, question, and derive conclusions is more effective than passive lecture-based delivery (Driscoll, 2019). In the context of physics teacher preparation, the integration of guided-inquiry strategies into teaching materials is not only relevant but methodologically urgent. Pre-service teachers must be trained through structured inquiry cycles—orientation, exploration, concept formation, application, and reflection—to ensure that conceptual understanding is built through evidence-based reasoning rather than memorization.

Building upon these considerations, the present research develops guided-inquiry-based teaching materials specifically for electricity–magnetism, focusing on core topics such as Coulomb's law, electric fields, magnetic induction, and electromagnetic applications. The module is designed with multi-tier problem tasks, experimental simulation sheets, and divergent-question prompts to stimulate scientific creativity. Through this approach, the developed teaching materials are expected to generate measurable improvements not only in conceptual understanding but also in creative dimensions, including fluency, flexibility, elaboration, and originality in scientific reasoning. Several recent studies support the effectiveness of inquiry-based and guided-inquiry physics teaching materials.

For instance, Nisa et al. (2024) document that the use of a 3D physics module under inquiry-based learning significantly improved students' creative thinking skills. Similarly, Nursabrina, Al Hasanah & Astra (2024) found that employing a guided-inquiry model assisted by interactive modules in elasticity topics increased students' critical-thinking scores substantially — with interpretation at 88%, evaluation at 93%, and inference at 89%. These findings reinforce the argument that developing guided-inquiry–based materials for complex topics such as electricity and magnetism is both timely and pedagogically justified.

Blended learning has also been widely adopted in education for its ability to improve learning outcomes and students' attitudes (Soylu & Akçayır, 2019). It combines face-to-face and online instruction to maximize the learning experience (Graham, 2019). Integrating blended learning with guided inquiry offers opportunities to create flexible and contextually rich learning environments (Garrison & Kanuka, 2004). This approach further supports the formation of sustainable learning communities (Vaughan, Cleveland-Innes, & Garrison, 2018). By leveraging technology, pre-service teachers can access materials independently and engage in classroom discussions more effectively.

Scientific creativity is a critical competency for pre-service physics teachers in meeting the challenges of 21st-century education (Runco, 2013). It encompasses the ability to generate new ideas, solve problems, and apply scientific concepts in novel contexts (Tiadarma, 2022). Prior research indicates that innovative learning models can improve aspects of scientific creativity, such as fluency, flexibility, and originality (Husni, 2020). Hence, developing teaching materials oriented toward scientific creativity is essential. This study aims to address this need through the development of a guided-inquiry and blended learning electricity–magnetism module.

Previous studies have demonstrated the effectiveness of inquiry-based modules in enhancing students' problem-solving skills (Yanti, Ibrohim, & Rosidin, 2021). Guided-inquiry-based modules help students learn more independently and systematically (Rambe, Silalahi, & Sudrajat, 2020). The integration of guided inquiry and blended learning has also been shown to improve students' science literacy (Nisrina, Jufri, & Gunawan, 2020). Therefore, the guided-inquiry and blended-learning electricity–magnetism module is expected to enhance the scientific creativity of pre-service physics teachers. This forms the basis of the present research, which examines the development, validation, and effectiveness of the module.

The purpose of this study is to develop guided-inquiry-based electricity–magnetism teaching materials with blended learning to improve the scientific creativity of pre-service physics teachers. The study also aims to validate the quality of the materials and test their effectiveness based on sub-indicators of scientific creativity. Its results are expected to contribute to the development of innovative teaching models for pre-service physics teachers. In addition, the study can serve as a reference for educators integrating blended learning and guided inquiry in their classrooms. Thus, this research plays an important role in improving the quality of physics instruction in higher education.

This study draws on systematic instructional development models to ensure the quality of the produced materials (Bonk & Graham, 2019). The electricity–magnetism module is designed to promote multimodal learning activities consistent with the principles of blended learning (Picciano, 2019). The success of developing teaching materials also depends on validation by experts in the field (Herawati & Setiawan, 2020). This validation covers content, construct, language, and technical aspects relevant to pre-service physics teachers. Through this procedure, the resulting teaching materials are expected to meet current learning needs.

Furthermore, the development of this module is directed at integrating components that enhance fluency, flexibility, elaboration, and originality of pre-service teachers' scientific thinking (Runco, 2013). The use of blended learning in the module provides flexibility for students to learn both independently and collaboratively (Garrison & Kanuka, 2004). This strategy aligns with the demands of 21st-century learning, which emphasizes critical and creative thinking skills (Driscoll, 2019). Therefore, this study is expected to make a significant contribution to improving the quality of physics education. Its findings can serve as a foundation for developing similar teaching materials in other courses.

Finally, the results of this study are expected to serve as a reference for higher education institutions in designing curricula that support innovative learning (Graham, 2019). The module can also serve as a model for the development of guided-inquiry and blended-learning teaching materials that may be adapted across science subjects (Vaughan, Cleveland-Innes, & Garrison, 2018). In this way, the developed materials have broad potential for enhancing the competencies of pre-service physics teachers. The research also opens opportunities for further studies on the effectiveness of similar approaches in different instructional contexts. This is essential for strengthening empirical evidence on the impact of blended learning and guided inquiry on scientific creativity.

METHOD

This research employed a research and development (R&D) design based on the 4D model: Define, Design, Develop, and Disseminate. In the Define phase, needs analysis, content review, and literature mapping were conducted to determine the form of the teaching materials, the integration of guided inquiry with blended learning, the topics to be included, supporting tools, and research participants. During the Design phase, the structure, flowchart, and storyboard of the guided-inquiry and blended-learning module were prepared to ensure each content element was ready for development. The research flow can be seen in Figure 1, which outlines the sequential stages of the study.

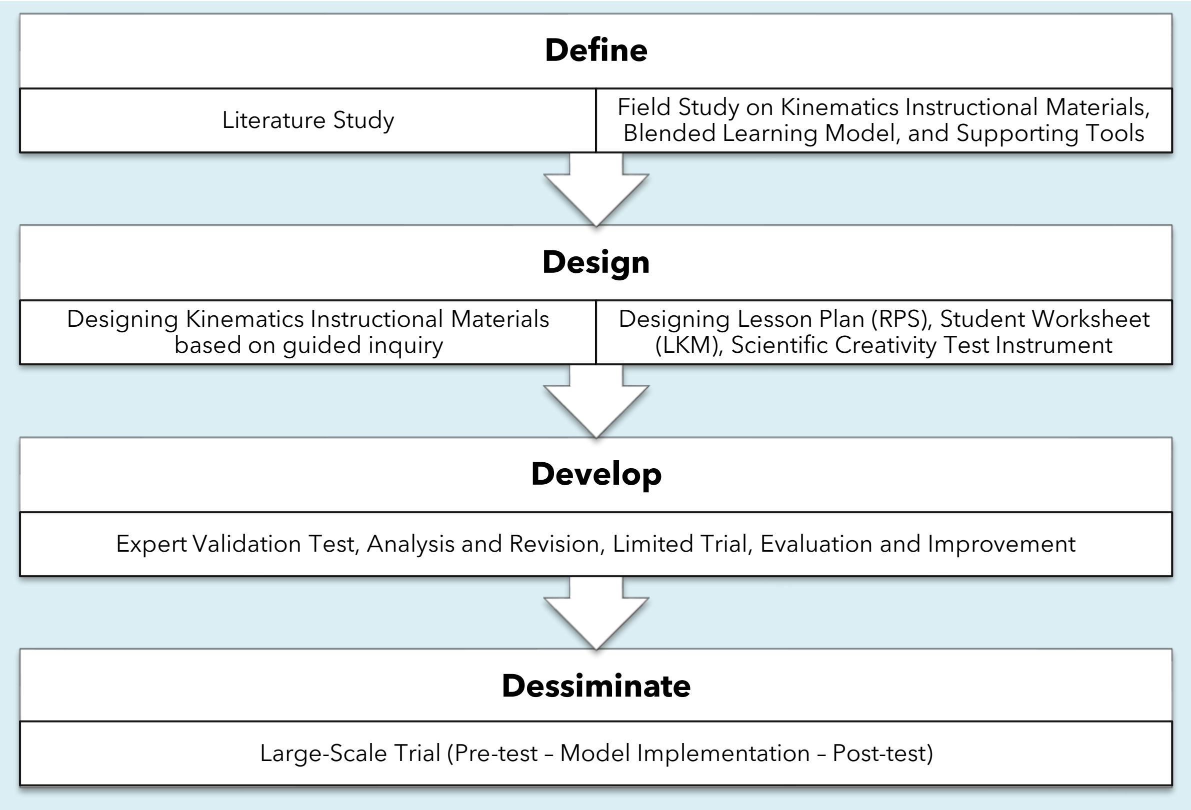

Figure 1. Experiment Design

The Develop phase involved creating the module components, validating them with experts, and conducting limited trials with second-semester physics education students to revise and refine the product based on feedback.

This study was conducted during the academic year of 2024/2025 at the Physics Education Department, Universitas Mataram. The research involved third-semester pre-service physics teachers enrolled in the Electricity–Magnetism course. A total of 62 participants were included in the large-scale trial, consisting of 31 students in the experimental class (guided-inquiry module) and 31 in the control class (conventional instruction). Participants were selected using a cluster random sampling technique based on existing class groupings. Prior to implementation, ethical approval was ensured through the completion of the official attendance and participation form, which all students filled out voluntarily as a declaration of willingness to participate in the study. The form served as a record of informed agreement, indicating that students understood the purpose of the research and consented to the use of their learning data for analysis while maintaining anonymity and confidentiality.

The instruments used in this study consisted of a scientific creativity test and a creativity rubric measuring seven indicators, including fluency, flexibility, elaboration, originality, scientific knowledge, scientific Imagination, and scientific problem solving. Evidence of instrument quality was ensured through expert judgment by three validators specializing in physics education, creativity studies, and educational assessment. Reliability testing using Cronbach's Alpha yielded a coefficient of 0.87, confirming internal consistency. The results obtained from the large-scale implementation phase will be analyzed using the N-gain technique (Hake, 1998) to measure the improvement in students' scientific creativity before and after the intervention.

In the Disseminate phase, the module underwent broader implementation and evaluation through a quasi-experimental design to assess its effectiveness and feasibility. The independent variable in this study was the guided-inquiry and blended-learning electricity-magnetism module, while the dependent variable was students' scientific creativity. Data were collected using a scientific creativity test integrated into the module, observation sheets, and Likert-scale questionnaires, covering seven indicators: unusual use, technical production, scientific imagination, hypothesizing, science problem solving, creative experimentation, and scientific product development (Astutik et al., 2015).

RESULTS AND DISCUSSION

Results

In this study, the independent variable was the Electricity–Magnetism teaching material designed using a guided inquiry approach integrated with blended learning, while the dependent variable was the scientific creativity of pre-service physics teachers. Scientific creativity was measured through indicators such as unusual use, technical production, scientific imagination, hypothesizing, science problem solving, creative experimentation, and science product development. These variables were selected to examine not only the feasibility of the developed materials but also their effectiveness in fostering higher-order thinking skills. By focusing on both the product quality and its impact on learners, this research provides a comprehensive assessment of how guided inquiry and blended learning can be systematically integrated into physics instruction to enhance students' scientific creativity.

This section presents the results of the expert validation and implementation analysis of the developed Electricity–Magnetism teaching materials based on guided inquiry combined with blended learning. The findings describe the quality of the product in terms of relevance, currency, readability, and presentation, as well as the reliability of its classroom implementation across several instructional phases. The complete research flow is illustrated in Figure 1, which outlines the process from literature review to the dissemination stage. Here is on Table 1 are the expert validation results.

The instrument validity analysis was conducted using Aiken's V, which involved three expert validators consisting of a physics education specialist, an assessment expert, and a learning media expert. Each expert assessed the indicators using a 4-point rating scale (1 = very inappropriate to 4 = very appropriate). The obtained

Aiken's V coefficients range between 0.80 - 0.89 (Bland and Altman, 1997), indicating a high content validity level with 95% confidence intervals falling within acceptable criteria (V > 0.80). In addition, instrument reliability was calculated using Cronbach's Alpha, producing a coefficient of α = 0.87, which demonstrates strong internal consistency and confirms that the instrument is statistically reliable for large-scale implementation

Table 1. Aiken's V score and agreement data for the blended learning-based science teaching materials

Component	Aiken-V Score	Percentage of Agreement
Relevant	0.83	88%
Up to-datedness	0.85	86%
Readability	0.78	90%
Presentation	0.81	86%
Average	0.81	87.5
Criteria	Very valid	Very suitable

The expert validation results (Table 1) show that the Electricity–Magnetism materials scored Aiken's V of 0.83 for relevance, 0.85 for currency, 0.78 for readability, and 0.81 for presentation. The overall mean Aiken's V score was 0.81, categorized as "highly valid." The percentage of agreement among experts was also high, reaching 88% for relevance, 86% for currency, 90% for readability, and 86% for presentation, with an overall average of 87.5% classified as "highly appropriate." These results confirm that the materials meet expert standards in terms of content, structure, language, and presentation, making them suitable for use by pre-service physics teachers to enhance scientific creativity.

Table 2. Data on the analysis results of learning implementation

Lesson Plan	Percentage of Learning Implementation (%), Phase -					
	1	2	3	4	5	6
Lesson Plan 1	90	100	87.5	90.625	81.25	93.75
Lesson Plan 2	100	81.25	87.5	81.25	87.5	100
Lesson Plan 3	92.5	81.25	100	84.375	93.75	100
Reliability	94.74%	89.66%	93.33%	94.55%	92.86%	96.77%
Category	Reliable					

Analysis of the learning implementation (Table 2) further indicates that the percentage of implementation across the six phases ranged from 81.25% to 100% for all three lesson plans (RPP). Reliability percentages across phases were 94.74% (phase 1), 89.66% (phase 2), 93.33% (phase 3), 94.55% (phase 4), 92.86% (phase 5), and 96.77% (phase 6). These results are categorized as "reliable," indicating that the learning activities were carried out consistently and in accordance with the designed scenarios.

Taken together, the high validity and reliability scores demonstrate that the developed Electricity–Magnetism teaching materials are not only feasible in terms of content but also effective in practice. The consistent implementation across phases suggests that both instructors and students were able to follow the guided inquiry and blended learning procedures as planned. This finding reinforces the suitability of the 4D development model (Define–Design–Develop–Disseminate) for producing high-quality instructional materials.

Moreover, the outcomes provide evidence that guided inquiry integrated with blended learning can effectively promote key indicators of scientific creativity such as fluency, flexibility, originality, and elaboration. Thus, the developed materials represent an innovative alternative for improving the quality of physics instruction in higher education and potentially in secondary schools as well.

The study measured the effect of the developed Electricity–Magnetism module on scientific creativity using a set of targeted indicators and normalized gain (N-Gain) as the primary metric of improvement. The independent variable was the guided-inquiry-blended-learning teaching material and the dependent variable was scientific creativity, operationalized through several subcomponents (see Table 3). N-Gain is used here to express the relative improvement from pretest to posttest (reported as a decimal or percentage), where higher N-Gain values indicate greater learning gains attributable to the intervention.

Table 3. Scientific creativity data for each sub-indicators

Indicator	Experimental				Control			
	Pre	Post	N-gain	category	Pre	Post	N-gain	category
SK (T-FLN)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SK (T-FLX)	30.0	75.5	65%	Medium	25.0	47.5	30%	Medium
SK (T-FLN) (2)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SK (T-FLX) (2)	20.0	20.0	0%	Low	30.0	40.5	15%	Low
SK (T-ORG) (2)	25.0	47.5	30%	Medium	40.0	55.0	25%	Low
SK (T-FLN) (3)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SK (T-FLX) (3)	35.0	70.8	55%	Medium	45.0	72.5	50%	Medium
SK (T-ORG) (3)	30.0	44.0	20%	Low	35.0	61.0	40%	Medium
TP (I-FLN)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
TP (I-T-FLN)	40.0	61.0	35%	Medium	38.0	62.8	40%	Medium
TP (I-T-ORG)	30.0	40.5	15%	Low	50.0	60.0	20%	Low
SI (I-FLN)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SI (I-FLX)	28.0	74.8	65%	Medium	30.0	61.5	45%	Medium
SI (I-FLN) (2)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SI (I-FLX) (2)	45.0	58.8	25%	Low	20.0	52.0	40%	Medium
SPS (FLN)	40.0	40.0	0%	Low	40.0	40.0	0%	Low
SPS (ORG-T)	22.0	53.2	40%	Medium	28.0	64.0	50%	Medium
SPS (I-ORG)	33.0	56.5	35%	Medium	40.0	58.0	30%	Medium

To make the table fully transparent, each abbreviation is defined and exemplified in the context of assessment. SK (Scientific Knowledge) assesses students' factual and conceptual understanding of electricity–magnetism as well as their ability to apply that knowledge in problem contexts; when followed by a parenthetical label such as (T-FLN), it denotes that this understanding was evaluated via Think tasks (T) and measured on the Fluency (FLN) dimension. TP (Technical Production) refers to students' capacity to create or produce technical artifacts or procedures (e.g., constructing circuits, writing experimental protocols); TP (I-T-FLN) therefore indicates technical production measured in Integration tasks (I) with an emphasis on Think-Fluency. SI (Science Imagination) captures the ability to generate hypothetical scenarios, mental models, or novel explanations in science; SI (I-FLX), for example, denotes science imagination assessed in integrated tasks for Flexibility (FLX). SPS (Science Problem Solving) evaluates systematic approaches to solving scientific problems and designing investigations; SPS (I-ORG) would mean problem solving within integrated tasks, scored on Originality (ORG). The letters I and T indicate the type of assessment task: I = Integration (tasks that combine multiple skills or modalities) and T = Think (tasks emphasizing cognitive processes and reasoning). The creativity dimensions are defined as: FLN (Fluency) — quantity of relevant ideas or responses; FLX (Flexibility) — variety or diversity of idea categories; ORG (Originality) — novelty or uniqueness of ideas.

Discussion

The present study demonstrates that the guided-inquiry, blended-learning based electricity–magnetism module significantly improved scientific creativity among prospective physics teachers. The moderate to high N-gain scores across multiple creativity indicators suggest that this instructional model effectively fostered components such as flexibility, elaboration, and originality. These findings align with those of Nisrina, Verawati & Hikmawati (2025), who reported that guided-inquiry-based electricity–magnet teaching materials yielded moderate–to–high N-gain scores on all eight scientific-creativity indicators (originality, fluency, flexibility, elaboration, problem sensitivity, scientific imagination, hypothesis formulation, and experiment design) for pre-service physics students (Rusli et al., 2025).

The positive impact observed in this study is consistent with the broader empirical evidence on the efficacy of inquiry-based learning in enhancing higher-order thinking skills. A recent meta-analysis concluded that inquiry-based science education leads to significant improvements in students' critical thinking and science process skills across diverse educational levels. Moreover, similar research applying guided-inquiry to physics topics has demonstrated substantial gains in students' critical thinking when supported by digital tools (e.g., virtual labs or simulations), reinforcing the idea that multimodal, student-centered learning environments support deeper cognitive engagement (Rusli et al., 2025). Importantly, beyond mere replication of prior work, the current study adds nuance by integrating a blended-learning framework with guided inquiry for electricity–magnetism — a domain often considered abstract and conceptually challenging (Nisrina et al., 2025). By doing so, the module enables flexible access to resources and self-paced exploration, which may reduce cognitive load and encourage iterative experimentation and reflection. This pedagogical design likely contributed to the observed improvements in creativity indicators, especially those related to flexibility and elaboration, by allowing learners more time and autonomy to reorganize and refine their thinking.

Comparatively, when set against similar studies in the literature, the N-gain values and consistency across multiple creativity indicators indicate a degree of novelty and practical significance. For instance, while many previous investigations focused on single aspects — such as critical thinking or argumentation skills — using guided inquiry (e.g., elasticity or momentum topics) (Doyan et al., 2023), the current research measures a broader, multi-dimensional construct ("scientific creativity") and demonstrates consistent improvement across all sub-indicators. This breadth strengthens the case that well-designed guided-inquiry materials, when blended with flexible learning modalities, can holistically develop the kind of creativity and scientific reasoning skills needed by future physics educators in the 21st century.

To highlight the significance of the module's impact, the N-Gain trends must be discussed through comparison with recent scholarly outcomes. Interpretation of the observed pattern benefits from alignment with recent findings. The high N-Gain values in flexibility indicators — particularly on SK (T-FLX) and SI (I-FLX) — reinforce research showing that guided-inquiry environments broaden students' cognitive pathways, enabling them to generate multiple alternative solutions in physics problem contexts. Interpretation of the observed pattern benefits from alignment with recent findings. The high N-Gain values in flexibility indicators — particularly on SK (T-FLX) and SI (I-FLX) — reinforce research showing that guided-inquiry environments broaden students' cognitive pathways, enabling them to generate multiple alternative solutions in physics problem contexts. Similar findings were reported where guided-inquiry significantly improved creative-thinking dimensions over direct instruction, especially flexibility and divergent processing (Saputri et al., 2023).

This trend is also consistent with the results of Nisrina et al. (2025), who observed strong post-treatment gains in flexibility indicators within an electricity–magnetism module. Comparable enhancements in cognitive variation are further documented across inquiry-based physics classrooms, particularly when students actively construct conceptual understanding rather than receive it passively (Rahman et al., 2023). Thus, the large flexibility shift in this study can be interpreted as a direct instructional impact of blended guided-inquiry design.

The moderate yet steady improvement observed in originality sub-indicators — such as SK (T-ORG) and SPS (I-ORG) — aligns with evidence that originality is often the slowest creativity dimension to develop. Nisrina et al. (2025) reported similar tendencies where flexibility increased rapidly post-treatment, while originality improved more gradually. This aligns with research noting that novelty-based creativity typically requires extended time, repeated inquiry exposure, or ill-structured cognitive challenges to reach optimal development (Suryani et al., 2024). Another study also emphasizes that originality improvement becomes more visible when learners engage in iterative experimentation and cross-representation reasoning processes rather than one-cycle intervention (Hidayat et al., 2023). These patterns support the interpretation that your module effectively stimulates novelty-oriented thinking, but extended cycles or higher-order inquiry may amplify future outcomes.

CONCLUSION

The findings of this study demonstrate that integrating the guided inquiry approach with blended learning in the development of Electricity and Magnetism teaching materials significantly enhances the scientific creativity of prospective physics teachers. Students showed substantial improvement across all eight creativity indicators, with particularly notable gains in elaboration, problem sensitivity, and flexibility. Moreover, gender-based analysis revealed that both male and female students benefited similarly from the intervention, underscoring the inclusive potential of the instructional design implemented.

SUGGESTION

For future research, it is recommended that this learning model be tested on other science topics beyond Electricity and Magnetism to examine the consistency of its impact. In addition, longitudinal studies could be conducted to assess the sustainability of scientific creativity gains over time and to explore more deeply the factors influencing the development of higher-order skills, such as experimental design and hypothesis generation.

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