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# Collaborative Problem-Solving Approach for Fostering Students' Creativity in Physics Practicum

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**Abstract:** Creativity is a crucial competence in 21st-century science education; however, physics laboratory activities in higher education are still predominantly conducted using verification-based models, which provide limited opportunities for creative thinking development. This study aims to examine the effectiveness of a Collaborative Problem-Solving Laboratory (CPSL) approach in enhancing the creativity of prospective physics teachers. The study employed a pre-experimental one-group pre-test–post-test design involving 20 undergraduate students enrolled in a Basic Physics Practicum course. Students' creativity was measured using an adapted Scientific Creativity Test encompassing fluency, flexibility, originality, and elaboration. Data were analyzed using the normalized gain (N-Gain) to determine the extent of improvement in each creativity indicator. The results revealed a substantial increase in students' creativity after the implementation of CPSL. Three indicators—Unusual Uses, Problem Finding, and Product Improvement—achieved high N-Gain values (0.7–0.8), while Creative Imagination, Creative Experimental Ability, and Product Design showed moderate improvement (0.4–0.6). These findings indicate that integrating collaborative problem-solving processes throughout pre-laboratory, laboratory, and post-laboratory activities can effectively promote students' creative thinking. It can be concluded that CPSL has the potential to transform physics laboratory practices from routine verification tasks into collaborative and creativity-oriented learning experiences.

**Keywords:** Creativity, Physics Lab, Collaborative Problem Solving, Physics Education

## Introduction

Creativity is increasingly recognized as one of the essential competencies in twenty-first-century education, particularly in science and technology. International studies consistently emphasize that creativity is crucial in enhancing students' learning experiences and equipping them to think critically, solve complex problems, and adapt to rapid technological changes (Govindasamy et al., 2024). Creativity is an essential component of science education, as it fosters students' exploration of novel concepts, the development of innovative solutions, and engagement in reflective learning practices. Science and technology educators are expected to establish learning environments that cultivate creative thinking as a fundamental component of general and scientific literacy (Zoabi, 2022). Furthermore, creative education holds the potential to mitigate educational disparities by establishing inclusive learning environments that foster collaboration, inquisitiveness, and innovative thinking (Ismail et al., 2018).

Laboratory activities play a pivotal role in the global advancement of science and engineering

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education. They enable students to transcend passive knowledge acquisition and actively engage with phenomena through hands-on experiments. By providing experiences that complement theoretical explanations, laboratories enhance the comprehension of abstract and intricate scientific concepts (Bretz, 2019; Raman et al., 2022). Well-designed laboratory practices are also believed to enhance students' motivation, curiosity, and creativity (Draper et al., 2021; Muliyadi et al., 2023; Yildirim, 2021). Furthermore, the quality of teaching and innovation in laboratory learning has been identified as a crucial factor in the provision of meaningful science education (Grushow et al., 2022). Despite its potential, laboratory education frequently encounters challenges in its implementation. These challenges encompass rigid instructional models and the absence of standardized methods for assessing creativity as a learning outcome (Asiksoy, 2023).

In the laboratory setting, physics education often adheres to a procedural approach, emphasizing theoretical validation rather than fostering independent exploration and problem-solving. Students diligently follow experimental procedures as prescribed, lacking the opportunity to innovate, adapt, or develop effective strategies for tackling complex challenges. Consequently, the development of advanced cognitive abilities, including creative, critical, and collaborative thinking, is hindered. Practicum sessions frequently become routine activities, diminishing the role of students as active seekers of knowledge and meaning within the realm of physics (Ermayanti et al., 2021; Unwakoly et al., 2024).

From a theoretical perspective, creativity in science learning is not merely an innate talent but a cognitive skill that can be systematically developed through appropriate learning environments (Soomro et al., 2022). Hu and Adey's scientific creativity framework conceptualizes creativity as a multidimensional construct comprising fluency, flexibility, originality, and elaboration, which are closely associated with students' ability to generate, modify, and refine scientific ideas (Hu & Adey, 2002). In laboratory contexts, these dimensions are expected to emerge when students are provided with opportunities to explore problems, propose alternative solutions, and iteratively improve experimental designs rather than merely follow predetermined procedures (Bretz, 2019; Coştu, 2024). Therefore, creativity development in physics laboratories requires instructional designs that explicitly support divergent thinking and idea construction processes (Draper et al., 2021).

To address these limitations, a learning approach is required that fosters active student participation in collaborative and creative problem-solving. One promising approach is the Collaborative Problem-Solving Laboratory (CPSL). This approach integrates collaborative problem-solving within the context of laboratory experiments through a systematic progression encompassing problem identification, idea exploration, experiment design, and result evaluation. CPSL not only facilitates the acquisition of conceptual knowledge but also cultivates students' creativity and interpersonal skills.

Numerous prior studies have demonstrated that Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) can enhance concept comprehension and critical thinking abilities (Arifah et al., 2021; Astalini et al., 2023; Kusdiastuti et al., 2020; Nurhasnawati et al., 2023; Permata Sari et al., 2022). Nevertheless, these approaches are predominantly employed in the context of theoretical classroom learning or primarily emphasize individual problem-solving. Research on laboratory learning that explicitly facilitates teamwork, creative exploration, and reflection through CPS remains significantly limited. Consequently, the integration of the Collaborative Problem Solving approach into the design of physics practicum constitutes a significant breakthrough that has not been extensively explored.

Despite strong theoretical support for creativity-oriented and collaborative learning, physics laboratory practices in higher education—particularly in the Indonesian context—remain largely verification-oriented and teacher-directed (Bretz, 2019; Ermayanti et al., 2021). This misalignment between theoretical expectations and instructional practice creates a gap in which students' creative potential is insufficiently developed (Coştu, 2024; Kruse et al., 2022). Moreover, while collaborative problem-solving has been widely studied in classroom-based learning, its systematic integration across all stages of laboratory activities, from pre-laboratory to post-laboratory phases, has received limited empirical attention (Michalsky & Cohen, 2021; Saputra et al., 2023). Consequently, there is a clear need for research that not only implements CPS within physics laboratories but also empirically examines its effectiveness in enhancing students' scientific creativity (Hidayah, 2023; Xu et al., 2023).

These limitations highlight a substantial research gap. Traditional physics laboratory models, characterized by rigid procedures and narrow objectives, are inadequate in fostering students' creative potential (Anoop et al., 2023). While international studies increasingly advocate for inquiry-based and problem-solving strategies, few empirical investigations in Indonesia have examined the systematic integration of Collaborative Problem Solving (CPS) within physics laboratory settings. At the same time, reliable methods for assessing creativity as an explicit learning outcome of laboratory activities remain scarce. This gap highlights the urgency of rethinking laboratory practices to be more student-centred, collaborative, and creativity-driven.

CPS has emerged as a promising pedagogical approach to address these challenges. CPS provides a supportive environment that enhances creativity and critical thinking by situating students in problem contexts that require teamwork, negotiation, and joint decision-making. (Hidayah, 2023; Michalsky & Cohen, 2021). In physics laboratories, CPS can foster student engagement by encouraging them to design and modify experimental procedures, explore alternative solutions, and collectively reflect on the outcomes of their investigations. These processes inherently promote creative thinking, requiring flexibility, originality, and elaboration. Research has also demonstrated that the collaborative nature of CPS enhances student engagement and motivation, thereby unlocking their creative potential (Muawiyah, 2024). Laboratories, therefore, can serve not only as spaces for verifying theories but also as fertile grounds for cultivating creativity through structured collaborative inquiry (Alnuaimi & Abdulhabib, 2023; Soomro et al., 2022).

The novelty of this study lies in its systematic integration of CPS into physics laboratory activities in Indonesian higher education, a context that has rarely been explored in previous research. Unlike earlier studies that primarily investigated inquiry-based or verification-oriented laboratories, this study focuses on fostering creativity by embedding collaborative problem-solving processes into every stage of practicum activities.

In light of these considerations, this study examines the effectiveness of incorporating a Collaborative Problem-Solving approach into physics laboratory activities to cultivate students' creative thinking. Specifically, the research investigates how CPS can transform laboratory practices from routine, verification-based tasks into dynamic, student-centered experiences that facilitate creative problem-solving and innovative thinking. The findings of this study are anticipated to contribute theoretically by expanding the discourse on creativity in science education and practically by providing empirical evidence and pedagogical insights for redesigning physics laboratories within Indonesian higher education institutions.

## Method

*Time and Location of the Research*

This research was conducted during the first semester of the academic year 2023/2024 at the Physics Education Study Program, Faculty of Teacher Training and Education, Lambung Mangkurat University, Indonesia. The study was carried out as part of the Basic Physics Practicum course, which includes laboratory activities on electricity and magnetism.

*Type of Research*

This study employed a pre-experimental design with a one-group pre-test–post-test structure. The design was chosen to determine the effectiveness of the Collaborative Problem-Solving approach in fostering students' creativity during physics laboratory activities. By comparing students' creativity scores before and after the intervention, the study aimed to evaluate the extent of improvement attributable to implementing CPS.

*Population and Sample*

The population of this study consisted of undergraduate students enrolled in the Physics Education Study Program at Lambung Mangkurat University. The sample comprised 20 students who were taking the Basic Physics Practicum course. Participants were selected using purposive sampling, ensuring that all students experienced the same practicum content, instructional approach, and learning environment throughout the intervention.

*Development Stages (Implementation of CPSL)*

The intervention was implemented through a series of physics laboratory activities designed based on the CPSL framework. The CPSL stages were systematically integrated into three main phases: 1) Pre-Laboratory Phase, Students worked collaboratively to identify authentic problems, respond to conceptual questions, generate initial ideas, and design experimental procedures. 2) Laboratory Phase, Students conducted experiments in small groups, collected and analyzed experimental data, and evaluated the suitability of their experimental designs. 3) Post-Laboratory Phase, Students collaboratively reflected on experimental results, refined their conclusions, and prepared practicum reports.

*Data Collection Instrument*

Students' creativity was assessed using a test instrument adapted from Hu and Adey, which is designed to measure four main dimensions: fluency, flexibility, originality, and elaboration (Hu & Adey, 2002). Adaptation was carried out to align with the local context, both in terms of content and language, as well as the representation of electrical and magnetic materials that are the focus of learning. The test was administered twice: once before the intervention (pre-test) and once after the intervention (post-test).

*Data Analysis*

The collected data were analyzed using N-Gain scores to measure the extent of improvement in students' creativity. The N-Gain was calculated by comparing pre-test and post-test scores using the formula proposed by Hake. The categorization of N-Gain scores followed the standard classification: high ($g > 0.7$), medium ($0.3 \le g \le 0.7$), and low ($g \le 0.3$).

Furthermore, the mean N-Gain for all participants was computed to ascertain the overall level of enhancement. The distribution of N-Gain categories among the participants was also analyzed to provide a comprehensive overview of students' creative development.

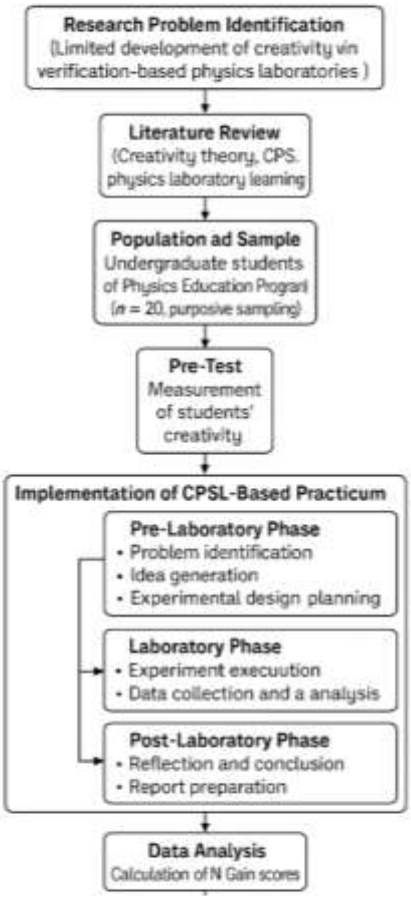


**Figure 1.** Research flow chart of the CPSL-based physics practicum

## Results and Discussion

The level of creativity exhibited by physics education students in this study was evaluated through six prominent indicators. The assessment was conducted via a pre-test and post-test, employing the normalized gain (N-Gain) formula to analyze the extent of score enhancement. The comprehensive results are presented in Table 1.

The results of measuring student creativity using the scientific creativity test showed a significant increase after implementing the Collaborative Problem-Solving model (Hu & Adey, 2002). Three indicators, namely Unusual Uses, Problem Finding, and Product Improvement, achieved high N-Gain values (0.7–0.8), while the indicators Creative Imagination, Creative Experiment Ability, and Product Design showed moderate increases (0.4–0.6). This increase can be attributed to the correlation between each stage of CPSL and the development of students' creativity dimensions.

**Table 1.** Data for the Creativity of Physics Education Students

| Indicator | Average score | | N-Gain | Category |
|---|---|---|---|---|
| | Pre Test | Post Test | | |
| Unusual Uses | 38.8 | 84.7 | 0.8 | High |
| Problem finding | 25.9 | 84.9 | 0.8 | High |
| Product improvement | 15.7 | 75.9 | 0.7 | High |
| Creative imagination | 32.9 | 74.9 | 0.6 | Medium |
| Creative experimental ability | 10.5 | 58.9 | 0.5 | Medium |
| Product design | 15.5 | 50.2 | 0.4 | Medium |

*High-Gain Creativity Indicators in CPSL-Based Practicum*

The Pre-Lab stage in collaborative learning holds significant importance in enhancing the problem-finding indicator of student creativity. The impact of N-Gain, which may vary across studies, is notable during this stage. Students are empowered to engage in intensive discussions to formulate practicum objectives, address conceptual questions, and identify research questions grounded in authentic problems. These group discussions not only facilitate the acceptance of existing problems but also cultivate divergent thinking skills, which are crucial for creatively defining problems (Ecevit & Kaptan, 2022; Murwaningsih & Fauziah, 2020).

Collaboration in groups can enrich the exploration of ideas and help students discover unidentified problems (Ecevit & Kaptan, 2022). This process aligns with the statement that group collaboration plays an important role in improving cognitive and metacognitive thinking skills (Ecevit & Kaptan, 2022). In addition to fostering innovative problem-solving approaches, these discussions enhance students' critical and creative thinking abilities. This aligns with research indicating that group discussions promote the development of robust divergent thinking skills(Wei, 2024). Efforts to increase student engagement in discussions and problem-solving positively impact their academic skills and enrich their overall learning experience (Beaty et al., 2021).

During the Idea Generation stage, students are empowered to generate ideas and alternative solutions that will be analyzed and consolidated into practical designs and hypotheses. This process contributes to an increase in the Unusual Uses indicator with an N-Gain of 0.8. Each group member is encouraged to contribute their ideas, fostering an atmosphere of diverse and innovative perspective exchange. This aligns with the characteristics of scientific creativity, emphasizing the importance of fluency of ideas and originality in problem-solving (Ponce-Delgado et al., 2024). Students discover new ideas through collaborative discussions and stimulate their critical and creative thinking skills.

Following the generation of ideas, the Exploration stage emerged as a highly effective phase in enhancing the Product Improvement indicator, achieving an N-Gain of 0.7. During this stage, students meticulously tested their initial concepts and refined their experimental designs. The significance of experiment-based learning in fostering a continuous cycle of refinement that stimulates creativity is evident in the observed improvement in students' proficiency in refining their practical designs (Adeoye & Jimoh, 2023; Tigre et al., 2024).

Furthermore, during the laboratory stage, students collect and analyze data obtained from laboratory practice. Although improvements in the Creative Imagination (N-Gain = 0.6) and Creative Experiment Ability (N-Gain = 0.5) indicators were identified in the moderate improvement category, student involvement in collaborative data analysis is significant. They learn to interpret experimental results and relate them to initial hypotheses, providing valuable experience in developing evidence-based creative thinking (Xu et al., 2023). Despite the substantial advantages of this approach, there are limitations, particularly in terms of time and practical facilities, which frequently restrict comprehensive exploration in designing novel experiments. The challenges encountered by students in the context of educational resources can diminish the potential for exploration related to more productive learning (Simelane-Mnisi, 2023). Laboratory experience significantly influences student empowerment in creative product development. However, time constraints and resource limitations in the learning environment can impede the full exploration opportunities necessary for optimal creativity development.

During the Post-Lab phase, students are expected to compile comprehensive reports that encompass the experimental outcomes, analysis, and conclusions. This process has the potential to positively impact the Product Design indicator, with an N-Gain of 0.4, although this improvement is still categorized as moderate. Collaborative report writing facilitates the integration of experimental findings, but the development of innovation design skills necessitates additional experience and robust infrastructure support.

Collaboration in report writing enables students to exchange perspectives and ideas, thereby enhancing their capacity to formulate superior product designs. Continuous practical experience is essential for students to fully master this design process. Student participation in projects centered around engineering and problem-solving can enhance their comprehension of pertinent concepts and support their aspirations to become innovators in their respective fields (Hsu & Rowland-Goldsmith, 2021).

*Implications of CPSL for Physics Laboratory Learning*

These findings suggest that each stage of CPSL contributes uniquely to the development of students' creativity. The pre-lab and ideation stages are particularly more significant in enhancing problem-solving and unconventional applications. Conversely, the exploration and practicum stages facilitate the development of product enhancements and experimental proficiency. These results support the scientific creativity theory proposed by Hu et al. (2002), which emphasizes the importance of idea fluency and originality in the context of learning (Coştu, 2024).

In addition, Asiksoy's research emphasizes that integrating 4C skills—Critical Thinking, Communication, Collaboration, and Creativity—into physics practicums can improve students' higher-order thinking skills(Asiksoy, 2023). This study demonstrates that physics laboratory designs that are not only oriented towards concept verification, but also provide space for students to collaborate, discover problems, generate original ideas, and refine experimental designs, have a positive impact on learning (Kruse et al., 2022; Saputra et al., 2023).

## Conclusion

This study demonstrates that the Collaborative Problem-Solving effectively enhances the creativity of prospective physics teachers. The implementation of CPSL resulted in a substantial increase in the indicators of Unusual Uses, Problem Finding, and Product Improvement (high category), while the indicators of Creative Imagination, Creative Experiment Ability, and Product Design were in the moderate category. These findings confirm that integrating CPS into physics practicums can transform laboratory activities from routine verification into collaborative and innovative learning experiences that foster creative thinking skills.

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**Author Contributions**
All authors contributed to the writing and revision of the article. The tasks of individual authors. e.g., SM contributed to data collection by conducting research; AS contributed to data analysis and interpretation; all authors have approved the final version.

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**Conflicts of Interest**
The authors declare no conflict of interest.in the publication of this scientific article.

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