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META-ANALYSIS OF PROJECT BASED LEARNING EFFECTS ON STUDENTS' CREATIVE THINKING IN PHYSICS LEARNING

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ABSTRACT

Developing creative thinking skills has become essential in the Fourth Industrial Revolution era. However, conventional teacher-centered instructional approaches have been found to be less effective in cultivating these abilities, particularly in complex subjects such as physics. Project-Based Learning (PjBL) has emerged as an instructional model with the potential to enhance students' creative thinking in physics classrooms. This study investigates the influence of PjBL on various dimensions of students' creative thinking skills in physics learning by synthesizing evidence from previous research. A meta-analysis approach was employed, with empirical data collected from Google Scholar using Harzing's Publish or Perish 8 and organized through Mendeley reference management software. The search identified 28 studies published between 2014 and 2023, of which 13 met the inclusion criteria and provided adequate statistical data for effect size calculation. The analysis produced an effect size of 1.03, classified as high, indicating that PjBL contributes approximately 84% effectiveness in improving creative thinking skills. Furthermore, 19 of the included studies examined specific creativity indicators, showing that elaboration demonstrated the greatest improvement, while flexibility showed the lowest gains. Overall, the findings confirm that PjBL has a substantial positive impact on students' creative thinking in physics education.

Keywords: Project-Based Learning; Creative Thinking; Physics Education; Meta-Analysis

ABSTRAK

Pengembangan keterampilan berpikir kreatif telah menjadi hal yang sangat esensial di era Revolusi Industri 4.0. Namun, pendekatan pembelajaran konvensional yang berpusat pada guru dinilai kurang efektif dalam menumbuhkan kemampuan ini, khususnya pada mata pelajaran yang kompleks seperti fisika. Project-Based Learning (PjBL) muncul sebagai model pembelajaran alternatif yang berpotensi meningkatkan berpikir kreatif siswa di kelas fisika. Penelitian ini bertujuan untuk menginvestigasi pengaruh PjBL terhadap berbagai dimensi keterampilan berpikir kreatif siswa dalam pembelajaran fisika dengan menyintesis bukti-bukti dari penelitian terdahulu. Pendekatan meta-analisis diterapkan dalam penelitian ini, dengan data empiris yang dikumpulkan dari Google Scholar menggunakan perangkat lunak Harzing's Publish or Perish 8 dan diorganisasikan melalui

Mendeley. Proses pencarian mengidentifikasi 28 studi yang diterbitkan antara tahun 2014 dan 2023, di mana 13 studi di antaranya memenuhi kriteria inklusi dan menyediakan data statistik yang memadai untuk perhitungan ukuran efek (effect size). Analisis data menghasilkan nilai effect size sebesar 1,03 yang dikategorikan dalam tingkat tinggi, menunjukkan bahwa PjBL memberikan kontribusi efektivitas sekitar 84% dalam meningkatkan keterampilan berpikir kreatif. Lebih lanjut, 19 dari studi yang disertakan menguji indikator kreativitas secara spesifik, yang menunjukkan bahwa indikator elaborasi mengalami peningkatan paling tinggi, sedangkan indikator fleksibilitas menunjukkan peningkatan paling rendah. Secara keseluruhan, temuan ini mengonfirmasi bahwa PjBL memiliki dampak positif yang signifikan terhadap kemampuan berpikir kreatif siswa dalam pendidikan fisika.

***Kata Kunci**: Project-Based Learning; Berpikir Kreatif; Pendidikan Fisika; Meta-Analisis*

A. Introduction

The rapid development of science and technology in the 21st century requires educators to adapt instructionally to cultivate competencies relevant to the modern era (Devanda, 2023). The educational process in schools must shift toward preparing students to face evolving global demands by fostering independent learning, efficient information retrieval, and high cognitive-practical skills (Azmi, 2023). Within this context, creativity has emerged as a critical capability in the contemporary workforce, with the job market increasingly demanding individuals capable of generating innovative and beneficial concepts. Creativity not only enhances daily life but also plays a pivotal role in driving scientific innovation and providing strategies to solve complex real-world challenges, thereby preserving and nurturing societal well-being (Kwon & Lee, 2025). Consequently, cultivating creative thinking skills—defined as the capacity to formulate original, useful solutions and facilitate the disclosure of knowledge and imagination—has become a foundational priority in modern classrooms (Leasa et al., 2023).

To effectively develop these 21st-century talents, educational institutions can no longer rely solely on conventional, teacher-centered content delivery, which has proven less effective in promoting student autonomy. Instead, instruction must actively engage students in soft skills, such as critical thinking, collaboration, problem-solving, and creativity. Empirical evidence indicates that active learning environments significantly support creative expression. One prominent approach is Project-Based Learning (PjBL), an open-ended, long-term exploration model where students, under teacher guidance, collaborate to solve complex issues, design practical solutions, and present authentic outcomes. By linking core academic content with everyday experiences, PjBL sparks learning interest and values independent innovation (Zhang et al., 2024). However, field realities show implementation gaps. In physics classrooms, some students still hesitate to participate fully in practicums and project assignments due to a lack of individual creative confidence, frequently relying on higher-achieving peers within their groups to assume dominant roles. This dynamic underscores the urgent need for a systematic instructional approach that uniformly elevates creative thinking capacities.

Science education, particularly physics, holds a special role in developing students who are capable of thinking critically, creatively, and rationally in response to technological advancements. As a fundamental discipline examining natural laws, behaviors, and material structures, physics naturally requires students to conduct research, experiments, and collaborative inquiry to construct conceptual clarity (Azmi, 2023; Hikmah et al., 2023). Unfortunately, a common problem in contemporary physics instruction is the lack of opportunities for students to actively participate, often leading to persistent conceptual misconceptions (Ansori & Nasrudin, 2019; Hasyim & Sujiono, 2023). Implementing PjBL addresses this issue by positioning students as active subjects of their educational experience, guiding them to construct knowledge, acquire meaningful procedures, and complete authentic work that reinforces deep conceptual understanding (Chistyakov et al., 2023).

While numerous studies confirm the benefits of PjBL, previous research findings display inconsistencies regarding its absolute impact. Variances frequently occur depending on the level of education (elementary, junior high, senior high, or higher education), the duration of implementation, and the specific metrics used to evaluate creativity.

Several related meta-analyses have explored these boundaries; for instance, Kwon and Lee (2025) reported that STEM-integrated PjBL significantly enhances student creativity with a very large effect size despite varying measurement instruments. Similarly, Zhan et al. (2024) and Hikmah et al. (2023) confirmed that project- and problem-based approaches exert a positive, substantial influence on critical and creative thinking within science and physics education. However, a comprehensive meta-analysis focusing strictly on the effect of PjBL on creative thinking skills specifically within physics learning—while systematically analyzing moderator variables—remains scarce. This represents a distinct gap in the existing literature.

To address this gap, the present study employs a meta-analysis approach to summarize, integrate, synthesize, and evaluate empirical data from previous research. This study aims to determine the overall effectiveness of the Project-Based Learning model on students' creative thinking skills in physics education. Furthermore, this research contributes to the literature by comparing the effects of PjBL across specific creativity indicators (fluency, flexibility, originality, and elaboration) and identifying key moderating factors, including educational levels, implementation durations, and supporting facilities. By providing a clear, aggregated, and objective overview, this meta-analysis offers valuable theoretical and practical insights to optimize instructional designs and foster sustainable 21st-century creativity in physics classrooms.

B. Methods

This research employs a quantitative design through the use of meta-analysis. Meta-analysis is a form of quantitative investigation that applies numerical findings and statistical procedures from multiple existing studies to organize and examine data more deeply, thereby achieving a comprehensive understanding (Chandra, 2011). It integrates results from several independent studies so that the combined data can be statistically reanalyzed (Santosa & Yulianti, 2020). Meta-analysis relies on the effect sizes reported across various studies, allowing meaningful comparison and interpretation (Fahrezi et al., 2020). Accordingly, the present study utilizes meta-analysis to synthesize empirical findings on the effectiveness of PjBL in enhancing students' creative thinking skills in physics learning.

The meta-analysis process implemented in this study follows the three stages recommended by Paloloang et al. (2020), namely:

1. Determining the inclusion criteria for selecting relevant studies.
2. Detailing the procedures for collecting empirical data and identifying research variables.
3. Describing the stages of data analysis.

Establishing inclusion criteria is essential to ensuring that the studies analyzed align with the research objectives. The selected studies were required to meet the following conditions:

1. Published between 2020 and 2024.
2. Derived from journal articles, conference proceedings, or national scientific sources.
3. Examined the influence of the PjBL model on students' creative thinking abilities in physics education.
4. Used experimental, pre-experimental, quasi-experimental, or classroom action research methods.
5. Involved at least one experimental and one control group whose outcomes could be compared, with one group receiving the PjBL intervention.
6. Provided sufficient statistical information for calculating effect size, including mean, chi-square values, standard deviations, sample sizes, or t-test results.

Empirical data were retrieved from the Google Scholar database using Harzing's Publish or Perish 8 software and organized in Mendeley reference management. Data collection aimed to identify relevant journal articles and proceedings using keywords such as "PjBL," "Creative Thinking," and "Physics Education." This search produced 28 articles published between 2014 and 2024. These articles were then screened using the established criteria, and only those that satisfied the inclusion requirements were retained for effect size computation to determine the overall influence of PjBL on creative thinking in physics education.

A coding sheet was developed to facilitate accurate data extraction. The required information included author names and publication years (2014–2024), research design, pretest and posttest means or sample sizes (n ≥ 30), standard deviations or t-values, and the formulas applied. Coding was conducted to compute effect size (ES), which represents the magnitude of the treatment effect across studies with different samples. The effect size was calculated using the appropriate statistical equations derived from the available data, as shown in Table 1, to estimate the relationship between the independent and dependent variables (Shorten & Shorten, 2013).

Tabel 1. Mathematical equation of effect size (ES)

Data Statistics	Mathematical Equation of ES	Formula (Fr)
Mean and SD for each group (posttest only)	$ES = \frac{\bar{x}_{experiment} - \bar{x}_{control}}{SD_{control}}$	Fr-1
Mean and SD for each group (pretest and posttest)	$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})experiment - (\bar{x}_{post} - \bar{x}_{pre})control}{\left(\frac{SD_{pre\ control} + SD_{pre\ experiment} + SD_{post\ control}}{2}\right)}$	Fr-2
Mean and SD for a single group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$	Fr-3
t value	$ES = t\sqrt{\frac{1}{n_{exp}} + \frac{1}{n_{control}}}$	Fr-4
Chi-square	$ES = \frac{2r}{\sqrt{1 - r^2}}; r = \sqrt{\frac{x^2}{n}}$	Fr-5

Once the effect size (ES) is obtained, it can be interpreted according to the effect size interpretations proposed by Cohen (1988) as shown in Table 2.

Table 2.Cohen's effect size interpretations

No	Effect Size (ES)	Interpretation
1	ES ≥ 0.8	High
2	0.2 ≤ ES < 0.8	Moderate
3	0 ≤ ES < 0.2	Low

Once the average effect size is obtained, the influence of the independent variable on the dependent variable can be interpreted according to Table 3 (Coe, 2002).

Table 3.Interpretation of the effect size (ES)

Effect Size (ES)	Influence (%)
0.0	50
0.1	54
0.2	58
0.3	62
0.4	66
0.5	69
0.6	73
0.7	76
0.8	79
0.9	82
1.0	84
1.2	88
1.4	92
1.6	95
1.8	96
2.0	98
2.5	99
3.0	99.9

C. Results and Discussion

The initial data collection phase retrieved 28 relevant scientific documents exploring the intersection of Project-Based Learning (PjBL), creative thinking, and physics education. Chronologically, these primary studies span a ten-year publication window from 2014 to 2024, with research activity peaking significantly across three distinct years: 2018 (accounting for 21% of the literature), 2022 (18%), and 2019 (14%).

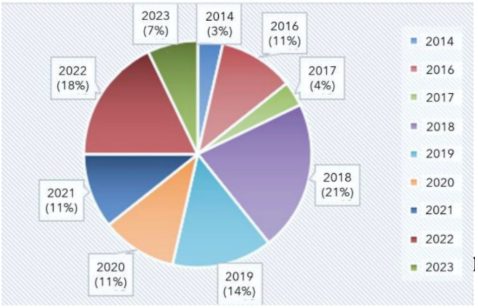

Figure 1. Distribution of studies by publication year

Methodologically, the gathered pool of literature displays a wide variety of research frameworks, notably utilizing Nonequivalent Control Group Designs (Andi et al., 2018; Cahyani & Viyanti, 2023; Nurfa & Nana, 2020; Risnaini et al., 2016; Sinta et al., 2022), Posttest-Only Control Group configurations (Aini et al., 2018; Dinantika et al., 2019; Fajrina et al., 2018; Firdaus et al., 2022), and various Pretest-Posttest designs (Abdullah et al., 2017; Fauziah et al., 2018; Khoiri et al., 2016; Mawarni & Sani, 2020; Ningsih et al., 2023; Sahida, 2021; Umamah & Andi, 2019; Utami et al., 2019). The remaining studies relied on One-Group Pretest-Posttest approaches (Amalia et al., 2019; Putri et al., 2020), Pre-Experimental or Quasi-Experimental structures (Khanifah & Saefan, 2016; Mulhayatiah, 2014; Rachmawati et al., 2018; Rohman & Husna, 2021; Safrina et al., 2022), Classroom Action Research (CAR) frameworks (Erisa et al., 2021; Fajaruddin, 2022; Medriati et al., 2022), and Mixed Methods featuring embedded experimental tracking (Sari et al., 2018).Following a systematic selection phase based on the availability of robust numerical metrics, the 28 collected documents were divided into two operational datasets. A total of 13 primary studies (comprising articles No. 1 to 13) provided sufficient statistical data—such as sample sizes (n), pretest/posttest means ($\bar{x}$), standard deviations (SD), or continuous t-test values—necessary to execute formal effect size calculations. Conversely, the remaining 15 articles were excluded from the meta-analysis due to insufficient or absent statistical parameters required for standardized effect size computation. Concurrently, an indicator mapping process was applied to the literature, revealing that 19 of the 28 studies actively evaluated granular creative thinking metrics, while 9 articles omitted specific indicator percentages.

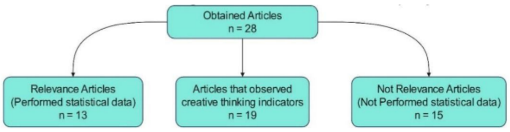

Figure 2. Mapping of collected research articles.

The statistical integration of the 13 eligible datasets yielded an overall cumulative average effect size (ES) of 1.03. According to Cohen's (1988) standard benchmark criteria, an effect size exceeding the 0.80 threshold is classified as high. The individual study effects within this matrix ranged from a moderate low of 0.43 (Khoiri et al., 2016) to an optimal peak of 3.09 (Amalia et al., 2019), with no studies exhibiting a low effect size interpretation.

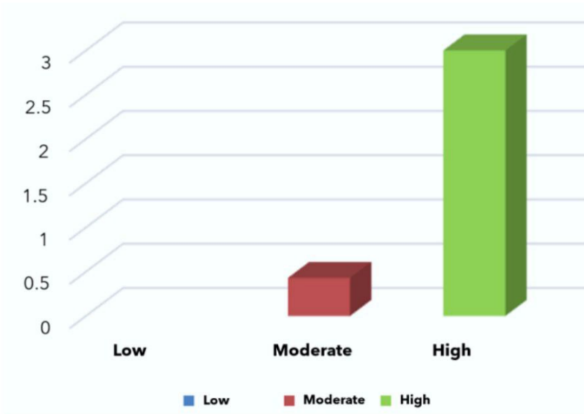

Figure 3. Interpretation of effect size of PjBL on students' creative thinking skills in physics education.

When converted using Coe's (2002) standardized percentage distribution, a cumulative ES of 1.03 implies that the implementation of PjBL delivers an approximate 84% effectiveness rate in expanding students' creative thinking capacities compared to traditional, teacher-centered instructional approaches. This prominent finding strongly aligns with previous meta-analytic investigations in science education; for example, Hidayah and Nuroso (2022) reported a high average ES of 0.82 from 10 articles, Sutria et al. (2023) established a high impact with an average ES of 1.39 from 11 studies, and Ananda et al. (2021) confirmed a high effect magnitude of 1.58 regarding PjBL's efficacy on physics-related creativity.The aggregated data from the 19 studies tracking explicit creative thinking dimensions reveal a compelling contrast between the highest and lowest developed metrics.

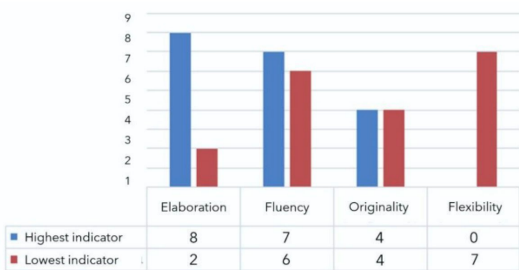

Figure 4. Highest and lowest creative thinking indicators

Synthesis of these indicators demonstrates that elaboration was identified as the highest-performing dimension across 8 separate research articles (e.g., Aini et al., 2018; Firdaus et al., 2022; Khoiri et al., 2016; Mulhayatiah, 2014; Sahida, 2021; Sari et al., 2018; Sinta et al., 2022). This structural trend occurs because the operational phases of PjBL—such as designing complex problems, formulating group blueprints, building structural prototypes, and refining final project features—naturally compel students to detail, expand, and systematically enrich their ideas. This aligns with findings by Sari et al. (2018), who noted that project tasks allow students to detail their concepts thoroughly, and Sinta et al. (2022), who observed that students developed highly detailed execution plans during collaborative project sessions. Consequently, proficient elaboration skills empower physics students to address multifaceted physical phenomena in a sequential, rigorous, and thorough manner.In contrast, flexibility was identified as the lowest-performing creative dimension, emerging as the weakest indicator across 7 distinct research articles (e.g., Abdullah et al., 2017; Amalia et al., 2019; Firdaus et al., 2022; Mawarni & Sani, 2020; Rohman & Husna, 2021; Sahida, 2021; Sari et al., 2018). This reoccurring limitation indicates that while students excel at expanding a single chosen project pathway, they face significant cognitive friction when required to shift perspectives, alter established approaches, or generate diverse alternative answers with complete physical reasoning when encountering unexpected experimental constraints (Firdaus et al., 2022). As noted by Sari et al. (2016), students frequently become confused and cognitively stuck on a single problem vector, leaving them unable to determine more efficient or elegant alternative solutions. This structural imbalance suggests that while PjBL effectively counteracts traditional classroom passivity, future applications of the model in physics education must intentionally introduce divergent thinking exercises and cognitive pivots to better cultivate student flexibility alongside structural elaboration.

D. Conclusion

The findings of this meta-analysis demonstrate that applying the PjBL model contributes a substantially strong effect on students' creative thinking skills in physics learning. From 28 studies that satisfied the inclusion criteria, 13 articles provided effect size data indicating a value of 1.03, corresponding to an interpretation level of 84%. Furthermore, among the 19 studies that reported specific creativity indicators, elaboration emerged as the most prominent improvement, while flexibility showed the weakest gains. These results confirm that PjBL is highly effective in improving students' creative thinking abilities in physics learning across different educational levels.

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