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The Influence of STEM-Oriented Project-Based Learning and Learning Motivation on Creative Thinking Skills at the Elementary School Level

Rulli Hari Utomo[1]✉, Sudiyanto[2] & Supianto[3]

[1]✉Universitas Sebelas Maret, rulliutomo@student.uns.ac.id, Orcid ID: 0009-0004-1958-009X
[2] Universitas Sebelas Maret, sudiyanto@staff.uns.ac.id, Orcid ID: 0009-0005-1906-2337
[3] Universitas Sebelas Maret, supianto@staff.uns.ac.id, Orcid ID: 0000-0003-2879-1572

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Abstract

The evolution of 21st-century education necessitates enhancing creative thinking skills from elementary education. Nonetheless, pedagogical methods in elementary schools remain predominantly traditional and have not incorporated numerous innovative frameworks, such as Science, Technology, Engineering, and Mathematics (STEM)-oriented Project-Based Learning (PjBL). This study seeks to: (1) evaluate the impact of the PjBL-STEM model on students' creative thinking skills; (2) assess the influence of learning motivation on creative thinking skills; and (3) examine the interaction between learning models and learning motivation regarding the creative thinking skills of elementary school students. The research employed a quasi-experimental design with two groups, involving 142 fourth-grade students from eight elementary schools in the Purwantoro Sub-district of Wonogiri Regency. Data were gathered using validated and reliable creative thinking assessments and learning motivation questionnaires. The two-way ANOVA results indicated that the PjBL-STEM model had a significant effect on students' creative thinking skills ($F(1,138) = 45.892$; $p < 0.05$; $\eta^2 = 0.247$) and revealed a significant interaction with students' learning motivation ($F(1,138) = 6.268$; $p < 0.05$). While the main effect of learning motivation was statistically significant ($F(1,138) = 10.884$; $p < 0.05$), this result should be interpreted with caution, as motivation was examined in this study as a moderating factor rather than a direct target of instructional treatment. The findings suggest that the use of PjBL-STEM in science education fosters the enhancement of student creativity, regardless of their motivation levels.

Keywords: Creative Thinking Skills, Elementary School, Learning Motivation, PjBL-STEM

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Abstrak

Evolusi pendidikan abad ke-21 mengharuskan peningkatan keterampilan berpikir kreatif dari pendidikan dasar. Meskipun demikian, metode pedagogis di sekolah dasar masih didominasi oleh metode tradisional dan belum memasukkan berbagai kerangka kerja inovatif, seperti Pembelajaran Berbasis Proyek (Project-Based Learning atau PjBL) yang berorientasi pada Sains, Teknologi, Teknik, dan Matematika (STEM). Penelitian ini bertujuan untuk: (1) mengevaluasi dampak model PjBL-STEM terhadap kemampuan berpikir kreatif siswa; (2) mengkaji pengaruh motivasi belajar terhadap kemampuan berpikir kreatif; dan (3) mengkaji interaksi antara model pembelajaran dan motivasi belajar terhadap kemampuan berpikir kreatif siswa SD. Penelitian ini menggunakan desain kuasi eksperimen dengan dua kelompok, yang melibatkan 142 siswa kelas IV dari delapan sekolah dasar di Kecamatan Purwantoro, Kabupaten Wonogiri. Data dikumpulkan dengan menggunakan tes kemampuan berpikir kreatif dan kuesioner motivasi belajar yang telah divalidasi dan reliabel. Hasil ANOVA dua arah menunjukkan bahwa model PjBL-STEM memiliki pengaruh yang signifikan terhadap kemampuan berpikir kreatif siswa ($F(1,138) = 45,892$; $p < 0,05$; $\eta^2 = 0,247$) dan menunjukkan adanya interaksi yang signifikan dengan motivasi belajar siswa ($F(1,138) = 6,268$; $p < 0,05$). Sementara efek utama dari motivasi belajar secara statistik signifikan ($F(1,138) = 10.884$; $p < 0.05$), hasil ini harus ditafsirkan dengan hati-hati, karena motivasi diperiksa dalam penelitian ini sebagai faktor moderator dan bukan sebagai target langsung dari perlakuan instruksional. Temuan ini menunjukkan bahwa penggunaan PjBL-STEM dalam pendidikan sains mendorong peningkatan kreativitas siswa, terlepas dari tingkat motivasi mereka.

Kata Kunci: Kemampuan Berpikir Kreatif, Sekolah Dasar, Motivasi Belajar, PjBL-STEM

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INTRODUCTION

The global education revolution increasingly underscores the significance of acquiring 21st-century competencies, such as digital literacy, critical thinking, and problem-solving skills. A pivotal element of these competences is higher-order thinking skills (HOTS), which are currently a primary emphasis of international organizations like UNESCO and OECD (González-Salamanca et al., 2020). Countries including Indonesia, Singapore, and Malaysia have implemented curricular policies that promote the incorporation of HOTS in elementary education (Chiong & Lim, 2022; Tanudjaya & Doorman, 2020). Nonetheless, despite advancements in policy, significant hurdles persist in classroom implementation, such as teacher preparedness, local cultural variances, and socio-economic obstacles (Chun & Abdullah, 2019; Kosasih et al., 2022). Strategies for learning, including brainstorming, constructivist learning, and problem-based approaches, have been recognized as helpful for promoting HOTS, while suitable evaluation systems remain in development (Liu et al., 2024; Wilson & Narasuman, 2020).

Within the framework of HOTS capabilities, creative thinking is a fundamental component as it fosters innovation and empowers the younger generation. Numerous studies indicate that the adoption of models and curricula designed to foster creativity can markedly enhance students' creative thinking skills (Dilekçi & Karatay, 2023; Saeed & Ramdane, 2022), particularly regarding ideation, cognitive flexibility, and innovative problem-solving (Akmam et al., 2024; Ritter et al., 2020). Moreover, training in creative thinking has demonstrated the capacity to enhance academic performance, conceptual comprehension, and facilitate other advanced cognitive skills (Saeed & Ramdane, 2022). Community-based initiatives, including youth empowerment programs utilizing design thinking, have enhanced self-efficacy and intergenerational collaboration beyond the school setting (To & Liu, 2021). Additionally, entrepreneurship and innovation training in professional contexts can cultivate creative dispositions. The cultivation of creative thinking skills is both imperative and important for equipping a resilient and innovative future generation (Avcı & Durak, 2023; Supriyadi et al., 2022).

Despite the national curriculum's shift towards enhancing 21st-century competencies, elementary education in Indonesia is predominantly characterized by a unidirectional, teacher-centered methodology with limited contextual relevance. Methods such as lectures and drills remain predominant in several classrooms, failing to foster the creative, collaborative, and problem-solving skills essential in contemporary society. This disparity highlights the contrast between the global expectations for 21st-century competencies and the traditional learning methodologies that remain deeply entrenched in elementary education. Tanudjaya & Doorman (2020) assert that despite implementing curriculum reforms, their implementation continues to encounter institutional and cultural impediments.

Research indicates that the adoption of novel models, such as Project-Based Learning (PjBL) and STEM, at the elementary school level has not been systematically extensive. A significant number of educators lack sufficient preparedness or comprehension of the proper execution of PjBL, which adversely impacts the quality of its implementation in practice (Du & Chaaban, 2020; Purwaningsih et al., 2020). While research on STEM has progressed significantly, studies on PjBL at the elementary level remain scarce and methodologically inconsistent (Ferrero et al., 2021; Rusnilawati et al., 2023). This method can potentially enhance students' learning outcomes and critical thinking skills, particularly in science and STEM (Chistyakov et al., 2023). The amalgamation of PjBL with the STEM methodology is purported to enhance educational outcomes in the contemporary technology landscape. In light of these challenges, several researchers advocate for the creation of educational frameworks that integrate inquiry, computational thinking, and problem-solving (Saad & Zainudin, 2022; Smith et al., 2022), alongside enhancing the professional identity of STEM educators to better equip them for the adoption of innovative curricula (Galanti & Holincheck, 2022).

The incorporation of the PjBL model with the STEM framework is gaining prominence in initiatives aimed at fostering creativity, exploration, and scientific competencies among elementary school students. This paradigm prioritizes contextual learning, necessitating student engagement in resolving real-world issues through projects, while also cultivating creative, critical, and collaborative thinking skills. Numerous studies indicate that PjBL-STEM positively influences students' cognitive, emotional, and psychomotor domains, enhancing learning outcomes and HOTS (Chistyakov et al., 2023; Santhosh et al., 2023). In light of technological advancements and the intricacies of global issues, this integration is anticipated to enhance learning in the digital age. In the Indonesian context, the PjBL-STEM model aligns closely with the principles of the Independent Curriculum, which promotes project-based, exploratory, and differentiated learning tailored to the needs and potential of students (Ferrero et al., 2021; Umar & Ko, 2022), rendering it an innovative, contextual, and applicable strategy for 21st-century education.

Moreover, learning motivation is foundational in student engagement and academic development, particularly at the early education level. Amabile's Componential Theory of Creativity (Fan & Cai, 2022) identifies intrinsic motivation as a critical driver of creative performance through its influence on exploration, persistence, and risk-taking. Likewise, Self-Determination Theory (Chiu, 2022) highlights intrinsic motivation as essential to fostering higher-order thinking and creativity. These theoretical perspectives position learning motivation as a key contributor to developing creative thinking skills. Motivation has been demonstrated to enhance learning efficacy in diverse contexts, including game-based learning methods that bolster academic motivation (Partovi & Razavi, 2019) and pedagogical strategies that address students' fundamental psychological needs to elevate intrinsic motivation and engagement (Conesa et al., 2022). Intrinsic motivation predominates students' learning experiences in physical education (Rojo-Ramos et al., 2022), whereas in literacy, genre preferences and perceptions of reading and writing activities significantly affect motivation levels (Alves-Wold et al., 2024; Ives et al., 2020). Additional studies indicate that motivation for reading and writing generally diminishes with increasing educational levels, thereby underscoring the significance of early motivational treatments (De Smedt et al., 2020).

In PjBL contexts like PjBL-STEM, motivation serves as both a driving variable and a moderating factor influencing the efficacy of the learning model. Therefore, a comprehensive understanding of motivation is essential for tailoring teaching strategies to align with the motivational characteristics of elementary school students, incorporating innovative methods such as digital storytelling and iterative computer-based learning (Aseery, 2024). Despite extensive research on the PjBL approach and STEM integration within 21st-century education, there remains a paucity of experimental studies at the elementary school level that concurrently examine the direct and interactive effects of innovative learning models on learning motivation. Previous studies have implemented STEM-oriented PjBL to foster students' creative thinking, showing positive results in both elementary and secondary education (Bulu & Tanggur, 2021; Oktarina et al., 2023; Putri et al., 2023; Zainil et al., 2022). However, most of these studies primarily focused on the main effects of instructional strategies and often overlooked the role of learning motivation as a potential moderating variable. Much research also primarily concentrates on main effects, neglecting to investigate the influence of motivation as a moderating variable that can impact learning efficacy (Du & Chaaban, 2020; Ferrero et al., 2021).

Furthermore, research regarding the implementation of STEM in project-based science education at the elementary level remains scarce and often lacks systematic rigor (Rusnilawati et al., 2023). Additionally, prior findings reveal methodological inconsistencies in both design and evaluation, complicating generalization (Chistyakov et al., 2023; Ferrero et al., 2021). For those reasons, this study seeks to address this gap by concurrently evaluating the impacts of PjBL-STEM and motivation on students' creative

thinking skills, while experimentally investigating the connection between the two.

This study, therefore, aims to: 1) evaluate the impact of the STEM-oriented PjBL (PjBL-STEM) model on the creative thinking skills of elementary school students; 2) assess the influence of learning motivation on creative thinking skills; and 3) examine the interaction between the learning model and the level of learning motivation in affecting students' creative thinking skills. This study examines three objectives using a quasi-experimental design and two-way analysis of variance, aiming to elucidate the relationship between innovative learning strategies and affective dimensions in cultivating essential creative thinking skills for the 21st century.

METHODS

This research employed a quasi-experimental design with a pretest-posttest control group approach. This methodology enables researchers to evaluate the impact of the STEM-oriented PjBL model on students' creative thinking skills and examine the function of learning motivation as a moderating variable. This study involved 142 fourth-grade students from eight elementary schools in Purwantoro Sub-district, selected through cluster random sampling due to the natural grouping of students. The sub-district was chosen for its representativeness of rural public education, where lecture-drill remains dominant. Participants were divided evenly into experimental (PjBL-STEM) and control (lecture-drill) groups. The lecture-drill model was used as a comparator because it reflects the conventional instructional method widely applied in the region. The intervention lasted six 90-minute sessions over three weeks, aligning with school scheduling constraints while allowing sufficient exposure to measure short-term learning effects.

Creative thinking scores were categorized using percentile thresholds, while learning motivation was classified using a median split to distinguish between high and low groups for comparative analysis (Djafar et al., 2021). This technique was selected to enhance the treatment process within an unaltered learning environment, preserving the existing class structure and ensuring the validity of the experimental outcomes. The distribution of the sample for this investigation is given in Table 1.

Table 1. Distribution of Research Participants

Group	Number of Schools	Number of Students	Class
Experimental (PjBL-STEM)	4	71	Class IV
Control (Lecture-Drill)	4	71	Class IV
Total	8	142	

This study utilized two primary instruments: creative thinking skill tests and learning motivation questionnaires. The creative thinking skill assessment consisted of eight descriptive questions derived from Natural and Social Sciences (IPAS) educational content, aimed at evaluating students' capacities in articulating ideas, resolving issues, and formulating concepts coherently and innovatively. Meanwhile, the learning motivation questionnaire comprised ten binary-response items (agree/disagree) measuring students' general level of motivation toward IPAS learning. The total score was used to categorize students into high and low motivation groups.

Data collection was conducted by administering written assessments to students and distributing questionnaires completed with the assistance of teachers or parents. The specifics of the features and indications for each instrument are presented in Tables 2 and 3.

Table 2. Creative Thinking Skill Test Grid

Aspect	Indicators
Fluency	Proposing many ideas and answers for solving problems
Flexibility	Proposing ideas from different perspectives in solving problems
Originality	Proposing original and unusual ideas for solving problems
Elaboration	Explaining ideas in detail and completely solving problems

Table 3. Learning Motivation Questionnaire Grid

Aspects	Indicators
Intrinsic Motivation	Like science lessons, they are curious and enjoy solving problems
Extrinsic Motivation	Influenced by teacher praise, gifts, good grades, or learning competitions

This research instrument underwent multiple validation processes and reliability testing prior to its application in primary data collecting to ensure its practicality and dependability (Mustafa, 2020). Content validation was conducted by five professionals, including lecturers from the science course and school supervisors from Wonogiri Regency. The experts assessed the alignment of the indicators and questions with the measurement objectives, along with the construction and linguistic elements of the instrument. According to the validation results derived from Aiken's V formula, all instrument components were deemed valid, as they achieved scores over 0.80.

Furthermore, empirical validity was assessed using Pearson correlation analysis, indicating that all items surpassed the r-table threshold (0.349), confirming their validity. Reliability was then measured using Cronbach's Alpha, with separate analyses conducted for items 1–4 ($\alpha = 0.706$) and 5–8 ($\alpha = 0.631$). This division reflects the structural grouping of the test items, which were developed in two phases to represent different aspects of creative thinking tasks. Both reliability coefficients exceeded the 0.60 threshold, demonstrating acceptable internal consistency. Table 4 summarizes the instrument's validity and reliability results.

Table 4. Summary of Instrument Validity and Reliability

Instruments	Validity (r-count)	Reliability (Alpha)	Description
Creative Thinking Test (1–4)	0.505 – 0.569	0.706	Valid and Reliable
Creative Thinking Test (5–8)	0.611 – 0.792	0.631	Valid and Reliable
Learning Motivation Questionnaire	Aiken's V > 0.85	-	Validated by an expert

The data analysis was performed in multiple phases. The prerequisite tests comprised the Kolmogorov–Smirnov normality test and Levene's Test for homogeneity, both confirming that the data satisfied the requirements of normal distribution and homogenous variance (Mustafa, 2020). The balance assessment utilizing an independent samples t-test confirmed that the experimental and control groups were in comparable beginning conditions. The primary analysis employed a two-way ANOVA with uneven cell sizes to examine the impact of learning models, learning motivation, and their interactions on creative thinking skills. The investigation proceeded with a comparative examination of means among cells to investigate additional disparities. The research procedure encompassed the preparation and validation of instruments, determination of samples via cluster random sampling, execution of pre-tests, administration of treatments over six sessions using the PjBL-STEM model for the experimental group and lecture-drill for the control group, culminating in a post-test and statistical analysis of the results.

RESULTS AND DISCUSSION

Students' Creative Thinking Skills

Data on creative thinking skills from 142 fourth-grade elementary students indicated a significant performance disparity between the experimental and control groups. The experimental group utilizing the PjBL-STEM model demonstrated a greater improvement in scores compared to the control group employing the lecture-drill strategy. Both groups had comparable initial conditions in the pre-test, although they diverged dramatically following six learning sessions. The research revealed that the experimental group exhibited an average score increase of 13.68 points, rising from 65.23 in the pre-test to 78.91 in the post-test. Conversely, the control group had a mere rise of 6.49 points, rising from 64.85 to 71.34. The standard deviations of both groups remained steady, indicating continuous data

variability over the treatment. Moreover, the maximum score in the experimental group (95) surpassed that of the control group (88), reinforcing the PjBL-STEM strategy's efficacy. The findings demonstrate that STEM-integrated PjBL markedly enhances students' creative thinking skills, particularly fluency, flexibility, originality, and elaboration, as delineated in Table 5 of the analytical findings.

Table 5. Descriptive Statistics of Creative Thinking Skill

Group	Test	N	Mean	SD	Min	Max	Gain Score
Experimental (PjBL-STEM)	Pre-test	71	65.23	8.45	48	82	13.68
	Post-tes	71	78.91	7.92	62	95	
Control (Lecture-Drill)	Pre-test	71	64.85	8.12	46	81	6.49
	Post-tes	71	71.34	8.76	54	88	

Apperception is a process that cannot be separated from the steps of learning. Apperception plays a crucial role in helping students understand new material and establish connections between previously taught material and future material.

During the learning dissemination program in the digital era, the writers have interviewed some teachers at school, they are Ms. AM, S.Pd, Ms. SL, S.Pd and Ms. IA, S.Pd.

Ms. Ama, S.Pd, a teacher in Gorontalo city, stated that the process of apperception left her in confusion, and she even sometimes neglected the process. Ms. AM revealed that she was checking attendance and performing other simple activities, such as assessing the condition of the students, as part of a perception process in her class. Whereas, the process of apperception should be a wide, complex study and involve the metacognition process of the student.

Data Suitability Test for Advanced Analysis

Prerequisite tests verified that the data met the two-way analysis of variance assumptions. The data passed normality, homogeneity, and balance tests for inferential statistical analysis. The Kolmogorov-Smirnov normality test showed all data groups were normally distributed ($p > 0.05$). Levene's homogeneity test also showed that both the pre-test ($p = 0.621$) and post-test ($p = 0.347$) group variances were homogeneous. The balancing test utilizing the independent t-test exposed no significant difference in beginning conditions between experimental and control groups ($t = 0.274$, $p = 0.784$). If all statistical assumptions are met, two-way ANOVA can be used confidently to evaluate the study hypothesis. Table 6 summarizes the prerequisite test findings.

Table 6. Statistical Prerequisite Test Results

Type of Test	Group	Score	Sig.	Decision
Normality				
Kolmogorov-Smirnov	Pre-test Experiment	0.089	0.200	Normal
	Post-test Experiment	0.093	0.186	Normal
	Pre-test Control	0.076	0.200	Normal
	Post-test Control	0.084	0.200	Normal
Homogeneity				
Levene's Test	Pre-test	0.245	0.621	Homogeneous
	Post-test	0.892	0.347	Homogeneous
T-test				
Independent t-test	Post-test Experimental & Control	0.274	0.784	Balanced

The Influence of Learning Models on Creative Thinking Skills

The two-way ANOVA results indicated that the learning model had a significant effect on students' creative thinking scores ($F(1.138) = 45.892$, $p < 0.05$), with an eta squared value of 0.247, representing a large effect size. As shown in Table 8, the average creative thinking score for students in the PjBL-STEM group ($M = 78.91$, $SD = 7.92$) was significantly higher than that of students in the lecture-drill group ($M = 71.34$, $SD = 8.76$), with a mean difference of 7.57 points. The 95% confidence intervals of both groups did not overlap, further supporting the statistical significance of the result. This suggests that the PjBL-STEM model is more effective in fostering creative thinking than conventional instruction.

Table 7. Summary of ANOVA Learning Model Factors

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.	η²
Learning Model	2847.56	1	2847.563	45.892	0.000*	0.247
Learning Motivation	1263.44	1	1263.447	20.356	0.000*	0.128
Model × Motivation	389.12	1	389.124	6.268	0.014*	0.043
Error	8567.89	138	62.087			
Total	13068.02	141				

*Significant at α = 0.05

Table 8. Comparison of Averages of Creative Thinking Based on Learning Models

Learning Model	N	Mean	SD	95% Confidence Interval
PjBL-STEM	71	78.91	7.92	[77.04 - 80.78]
Lecture-Drill	71	71.34	8.76	[69.27 - 73.41]
Mean Difference		7.57		

In addition, the ANOVA revealed that learning motivation had a significant main effect on creative thinking scores ($F(1,138) = 20.356$, $p < 0.05$, $\eta^2 = 0.128$), indicating that students with higher motivation achieved better creative thinking outcomes across learning models. However, this main effect is further nuanced by the significant interaction effect between learning model and motivation ($F(1,138) = 6.268$, $p < 0.05$), analyzed in the subsequent section.

Comparison of Creative Thinking Skill Based on Group Combination

To explore the interaction effects between learning models and motivation levels, students were categorized into four groups based on a combination of instructional approach (PjBL-STEM vs. lecture-drill) and learning motivation (high vs. low). Motivation levels were classified using a median split of total motivation scores. The resulting groups were:

(1) High motivation with PjBL-STEM,
(2) Low motivation with PjBL-STEM,
(3) High motivation with lecture-drill, and
(4) Low motivation with lecture-drill.

A post hoc Tukey HSD test was then conducted to compare creative thinking scores across these combinations.

Table 9. Pairwise Comparison between Combinations

Comparison	Mean Difference	Sig. (p)	Interpretation
High PjBL-STEM vs Low PjBL-STEM	7.69	0.002*	Significant
High PjBL-STEM vs High Lecture	8.87	0.000*	Significant
High PjBL-STEM vs Low Lecture	13.74	0.000*	Significant
Low PjBL-STEM vs High Lecture	1.18	0.892	Not Significant
Low PjBL-STEM vs High Lecture	6.05	0.013*	Significant
Low PjBL-STEM vs Low Lecture	4.87	0.048*	Significant

*Significant at α = 0.05

The table above indicates that integrating PjBL-STEM with elevated motivation yielded the strongest creative thinking skill (M = 82.45), considerably distinct from all other combinations. Notably, students with low motivation in the PjBL-STEM group (M = 74.76) did not substantially vary from those with strong motivation in the lecture-drill group (M = 73.58). The PjBL-STEM paradigm effectively mitigated low student motivation. Integrating lecture-drill with minimal motivation yielded the lowest score (M = 68.71), which is considerably distinct from all other combinations. This research underscores the necessity of adopting novel learning strategies, particularly for students with diminished motivation, to enhance the cultivation of creative thinking skills.

This study effectively demonstrated the three established objectives. The PjBL-STEM model significantly enhances creative thinking skills ($F = 45.892$, $p = 0.000$, $\eta^2 = 0.247$), demonstrating a 7.57-point superiority compared to lecture-drill methods. Learning motivation significantly influences

performance ($F = 20.356$, $p = 0.000$, $\eta^2 = 0.128$), with highly motivated students outperforming others by 5.79 points. Interestingly, a notable interaction exists between the learning model and motivation ($F = 6.268$, $p = 0.014$), with the distinct observation that PjBL-STEM can mitigate poor student motivation. As such, the PjBL-STEM approach is demonstrated to be more effective in enhancing the creativity of elementary school students, with motivation serving as a moderating factor that amplifies the efficacy of STEM-integrated PjBL.

Discussion

This study's findings affirm that the STEM-oriented PjBL model (PjBL-STEM) significantly enhances the creative thinking skills of elementary school students. The experimental group consistently achieved higher ratings than the control group, reinforcing this method's efficacy in enhancing fluency, flexibility, originality, and elaboration. A collaborative, contextual, and real-world problem-solving learning environment enables students to freely explore concepts, cultivate innovative solutions, and articulate their ideas with greater originality and depth. This indicates that PjBL-STEM fosters active engagement and cultivates a comprehensive environment that enhances creativity. This finding aligns with prior research that underscores the significance and immediacy of introducing STEM in elementary education. Research by Purwaningsih et al. (2020) indicates that elementary school students have notably positive views towards STEM and 21st-century skills. Innovations in educational methodologies, like makerspace integration (Douglass & Verma, 2022) and STEM-oriented flipped learning (Rusnilawati et al., 2023), have demonstrated efficacy in fostering crucial learning competencies in the digital age. The trend of generating STEM-based teaching materials in Indonesia is rising and exhibits a favorable effect on student learning outcomes (Nuraeni et al., 2021). STEM is increasingly advocated as a domain for educational equity, encompassing arts integration (STEAM) and enhancing data literacy within the foundational curriculum (Ives et al., 2020; Ow-Yeong et al., 2023). Consequently, the findings of this study not only reinforce the current literature but also validate that a project-based STEM approach can effectively enhance children's creative thinking skills from an early age.

This study's results prove that learning motivation significantly impacts the creative thinking skills of elementary school students. Students exhibiting great drive typically demonstrate superior proficiency in generating creative, adaptable, and comprehensive ideas. This discovery aligns with the tenets of Self-Determination Theory (Evans et al., 2024; Rothes et al., 2022), underscoring that intrinsic desire fosters profound cognitive engagement. When fundamental needs like autonomy, competence, and relatedness are satisfied, children exhibit increased motivation to engage actively in cognitive and problem-solving activities. Furthermore, Bandura's self-efficacy theory posits that confidence in one's skills fosters intellectual courage and perseverance in confronting learning obstacles (Alemayehu & Chen, 2023; Azila-Gbettor et al., 2021).

Contemporary studies corroborate these findings by emphasizing the significance of motivation and self-efficacy in cultivating higher-order cognitive skills. Research conducted by Stolk et al. (2021) and Koreshnikova & Avdeeva (2022) demonstrated a positive correlation between intrinsic motivation and critical thinking skills as well as academic achievement. Active learning methodologies, including flipped learning, constructivist methods, and gamification, have revealed an enhancement in student enthusiasm and creativity (Funa et al., 2021; Wannapiroon & Pimdee, 2022). Motivation and self-efficacy are significant indicators of learning engagement across diverse educational settings, including online and cross-cultural collaborative learning (Chiu, 2023; Poort et al., 2023). Consequently, establishing a learning environment that promotes autonomy and competence is crucial for nurturing student creativity from elementary school onward.

The role of learning motivation is notably evident in the relationship between the learning model and student characteristics. Statistical analysis indicates a significant interaction between PjBL-STEM and the

degree of learning motivation on creative thinking skills, with an F value of (1.138) = 6.268 and p = 0.014. The efficacy of PjBL-STEM extends beyond highly motivated students, positively influencing those with low motivation. This finding corroborates the perspective that PjBL can more uniformly stimulate intricate cognitive processes, as it offers a controlled yet flexible learning environment conducive to investigation and reflection, even for students with initially lower engagement (Ferrero et al., 2021; Umar & Ko, 2022). This model's explorative, collaborative, and contextual environment enables all students to optimally cultivate their creative potential, aligning with Chang & Chen's (2022) findings on the significance of flexibility in learning approaches for enhancing educational outcomes across diverse student characteristics.

These findings also align with other recent research demonstrating the efficacy of PjBL and STEM methodologies in enhancing student engagement and learning outcomes across various educational settings (Khoiri et al., 2023; Ndiung & Menggo, 2024). The PjBL-STEM method indicates superior cognitive, emotional, and psychomotor outcomes relative to traditional methods (Rahim et al., 2024; Santhosh et al., 2023). Studies by Chistyakov et al. (2023) and Chang & Yen (2023) have found enhancements in critical thinking and problem-solving skills, even among students with varied learning styles. Notwithstanding implementation challenges, including restricted resources and technical obstacles, PjBL-STEM significantly enhances student motivation, learning efficacy, and intellectual engagement (Berestova et al., 2022; Umar & Ko, 2022). This technique is deemed pertinent for widespread application, particularly in fostering creative thinking skills among students from diverse motivating backgrounds.

Further, this study possesses numerous methodological advantages, such as a rigorously controlled quasi-experimental design, extensive statistical analysis encompassing precursor tests, two-way ANOVA, subsequent testing, and the use of equipment certified by experts and demonstrated to be dependable. The significance of the theme to the trajectory of national education policy, particularly in endorsing the Independent Curriculum that prioritizes PjBL and a scientific methodology, enhances the practical and contextual contributions of this study's findings (Berestova et al., 2022; Pramasdyahsari et al., 2023; Widyawati et al., 2024).

Nonetheless, several limitations exist, including the geographical scope confined to a single sub-district in Wonogiri Regency, the brief treatment duration (six sessions), and the inability to distinguish between intrinsic and extrinsic motivation types, despite their differing impacts on outcomes (Liu et al., 2024; Liu & Kim, 2024). Consequently, additional research is advised to duplicate this methodology across varied geographies and educational levels, while examining other factors such as student engagement, visual creativity, and attitudes towards STEM. Research must also investigate the influence of various types of motivation on the efficacy of the PjBL-STEM paradigm, enabling the development of more attuned learning strategies to student characteristics.

CONCLUSION

This study demonstrates that the STEM-oriented PjBL model (PjBL-STEM) significantly enhances elementary school students' creative thinking skills more than the traditional lecture-drill approach. Learning motivation also plays a crucial role, as highly motivated students tend to perform better in creative thinking tasks. Moreover, the interaction effect observed indicates that PjBL-STEM maintains its effectiveness even among students with lower motivation levels, suggesting its robustness across diverse learner profiles. These findings reinforce the value of contextual, collaborative, and student-centered pedagogical strategies in cultivating creativity.

To translate these findings into educational practice, it is recommended that schools and teachers integrate STEM-oriented PjBL into the elementary curriculum to foster creative thinking from an early age. Educators should also be supported through training and resource development to design authentic, inquiry-driven projects that promote active engagement. Additionally, educational policymakers are encouraged to recognize learning motivation as a critical factor in

creative development and to incorporate motivational strategies into national curriculum frameworks.

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