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Effectiveness of the Project Brainstorming Learning (PjBrs-L) Model in Enhancing Students' Self-Efficacy and Creative Thinking

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Abstract
The development of twenty-first-century competencies requires learning approaches that foster both cognitive and affective abilities, particularly creative thinking and self-efficacy. However, conventional science instruction often provides limited opportunities for students to generate original ideas, participate actively in collaborative learning, and develop confidence in solving authentic problems. This study aimed to examine the effectiveness of the Project Brainstorming Learning Model in enhancing students' creative thinking skills and self-efficacy during science learning. The research method used a quasi-experimental study using a one-group pretest-posttest design conducted on 12 students of the Biology Education Study Program, Jambi University.. Data were collected using a creative thinking essay test, a self-efficacy questionnaire, classroom observations, and an idea generation assessment. The data were analyzed using descriptive statistics, the Kolmogorov–Smirnov normality test, paired-sample t-tests, and simple linear regression. The findings revealed significant improvements in students' creative thinking ($t = -6.632$, $p < .001$) and self-efficacy ($t = -8.567$, $p < .001$) following the implementation of the Project Brainstorming Learning Model. Furthermore, regression analysis demonstrated a very strong positive relationship between the learning model and students' idea generation ($R = 0.991$, $R^2 = 0.981$, $p < .001$), indicating that the model substantially contributed to students' ability to generate creative ideas. These findings suggest that integrating structured brainstorming throughout project-based learning provides an effective instructional approach for simultaneously strengthening students' creative thinking, confidence, and collaborative idea generation. The study contributes empirical evidence supporting the use of innovative project-oriented learning models to develop essential competencies for twenty-first-century science education.

Keywords: Brainstorming; Creative thinking; Learning; PjBrs-L; Self-efficacy

INTRODUCTION

Twenty-first-century science education is increasingly expected to cultivate learners who can formulate original ideas, evaluate alternative explanations, collaborate across disciplinary boundaries, and respond confidently to unfamiliar problems. These expectations are particularly relevant to higher education, where students are not merely recipients of scientific knowledge but prospective professionals who must interpret complex information and apply disciplinary understanding to authentic situations. Within science teacher education, the development of creative thinking and academic self-efficacy is especially important because prospective educators must eventually design investigative learning experiences, respond to classroom challenges, and encourage students to approach scientific problems with intellectual curiosity. Nevertheless, the integration of creativity into university instruction remains uneven. Although creative thinking is widely acknowledged as an essential educational competency, its development requires more than assigning open-ended tasks or encouraging students to produce novel responses. Effective instructional design must provide opportunities for

generating ideas, evaluating their relevance, refining possible solutions, and learning from the outcomes of collaborative inquiry (Grey & Morris, 2024; Karunarathne & Calma, 2024; Guo et al., 2020). Consequently, science education requires pedagogical approaches that connect cognitive exploration with learners' confidence in their capacity to undertake challenging academic activities.

Creative thinking is a multidimensional capability involving the production, development, and evaluation of ideas that are both original and appropriate to a particular problem. In educational assessment, divergent thinking is frequently operationalized through fluency, flexibility, originality, and elaboration. Fluency concerns the generation of multiple responses, flexibility represents the capacity to approach a problem from different conceptual perspectives, originality reflects the relative novelty of proposed ideas, and elaboration refers to the development of ideas through relevant detail. Although these dimensions provide a useful framework for examining creative performance, they should not be treated as interchangeable indicators of a single cognitive process. Runco and Alabbasi (2024) demonstrate that divergent-thinking dimensions interact in predicting creative activity and accomplishment, while Sawyer (2021) conceptualizes creativity as an iterative process involving experimentation, improvisation, and revision. Similarly, Karunarathne and Calma (2024) highlight the importance of assessing creative-thinking competencies in higher education through appropriate instructional and evaluative practices. These perspectives suggest that creativity is not adequately developed through unrestricted idea generation alone. Students must also learn to compare alternatives, assess constraints, elaborate promising concepts, and revise initial solutions when confronted with new evidence.

The significance of creative thinking in scientific learning becomes clearer when considered alongside academic self-efficacy. Self-efficacy refers to individuals' judgments about their capabilities to organize and execute actions required to accomplish particular tasks (Bandura, 1997). In academic settings, these judgments influence students' willingness to undertake demanding activities, sustain effort, respond to difficulties, and regulate their learning behavior. Social Cognitive Theory identifies mastery experiences, vicarious experiences, social persuasion, and physiological or emotional states as important sources of self-efficacy. Accordingly, students may develop stronger confidence when they experience successful task completion, observe effective strategies demonstrated by peers, receive constructive feedback, and recognize improvement in their own performance. Schunk and DiBenedetto (2020) further explain how self-efficacy contributes to academic motivation and self-regulated learning, while Santos et al. (2025) demonstrate the relevance of project-oriented design activities to students' motivation and self-efficacy. These findings establish a rationale for examining academic self-efficacy within instructional environments that provide repeated opportunities for participation, experimentation, and successful project completion.

Creative thinking and self-efficacy are theoretically related, but their relationship should not be assumed to be automatic or unidirectional. A student may confidently complete familiar academic tasks without necessarily generating original ideas, whereas another may demonstrate considerable creative potential while remaining uncertain about the quality of their contributions. Research increasingly suggests that creative performance and confidence may develop through overlapping yet distinguishable learning experiences. Choi et al. (2024), examining a problem-based design-thinking project involving university students, reported improvements in ideational fluency and creative self-efficacy following collaborative activities. Stolz et al. (2022) similarly investigated creative problem-solving experiences and changes in creative self-efficacy among undergraduates. More recently, Liu et al. (2025) identified relationships among creative self-efficacy, critical thinking, metacognition, and problem-solving within engineering education. Taken together, these studies suggest that meaningful opportunities to formulate and develop ideas may contribute to students' confidence, while perceived competence may influence their willingness to engage in subsequent creative activity. However, these relationships remain context-dependent, and academic self-efficacy should not

be conflated with domain-specific creative self-efficacy.

Project-Based Learning (PjBL) provides a promising instructional foundation for integrating cognitive engagement, collaborative inquiry, and confidence-building experiences. Rather than organizing instruction exclusively around lectures or isolated exercises, PjBL engages learners in sustained activities directed toward investigating meaningful questions and producing tangible outcomes. Project activities commonly involve problem identification, planning, investigation, implementation, monitoring, presentation, and evaluation. Guo et al. (2020), reviewing project-based learning in higher education, identified cognitive, affective, behavioral, and product-related outcomes while noting that assessment practices frequently emphasized students' perceptions rather than direct evidence of learning processes and artifact quality. Markula and Aksela (2022) further demonstrated that authentic scientific inquiry, collaboration, and learner participation are central characteristics of project-based science instruction. Similarly, Almulla (2023) reported favorable relationships between project-based learning, student engagement, and academic achievement in technology-supported learning environments. These studies indicate that the educational potential of PjBL emerges from the organization of meaningful learning activities rather than from the mere requirement to complete a project.

Nevertheless, the reported benefits of project-based instruction vary considerably across educational settings. Wijnia et al. (2024), in a meta-analysis examining problem-based, project-based, and case-based learning, identified generally positive but heterogeneous effects on student motivation. Their findings suggest that motivational outcomes depend on the dimensions assessed, the academic discipline, and the scope of implementation. A more recent umbrella review by Farshad and Fortin (2026) identified consistently favorable directions of PjBL effects across academic and higher-order thinking outcomes, but also reported substantial limitations in the methodological quality of existing meta-analyses. Similarly, Kwon and Lee (2025) found positive associations between STEM-oriented project-based instruction and creativity while identifying considerable heterogeneity among the included studies. These findings are significant because they challenge interpretations of PjBL as an inherently effective pedagogical treatment. Instead, they indicate that its contribution depends on instructional coherence, the opportunities students receive to develop ideas, and the appropriateness of the instruments used to evaluate learning outcomes.

In science and biology education, project-oriented instruction is particularly relevant because scientific inquiry frequently requires students to formulate hypotheses, compare alternative interpretations, plan investigations, and communicate findings. However, project completion does not necessarily demonstrate that students have developed sophisticated creative-thinking processes. Learners may successfully produce a final artifact while relying heavily on familiar solutions or following predetermined procedures. Nurkanti et al. (2025), in a meta-analysis of project-based learning within university biology education, identified favorable outcomes for higher-order thinking while emphasizing variation in implementation contexts and assessment practices. Likewise, Fajrina et al. (2024) examined the relationship between project-based learning and differentiated instructional practices in biology education, highlighting the importance of adapting learning experiences to students' characteristics. These investigations suggest that science educators need to consider not only what students produce but also how they generate, evaluate, and revise scientific ideas throughout the learning process. The distinction is especially important when the intended outcomes include creative thinking and academic self-efficacy rather than subject achievement alone.

One instructional strategy that may strengthen these processes is brainstorming. Originally associated with collaborative idea generation, brainstorming encourages participants to propose multiple possibilities before selecting or rejecting particular alternatives. Its educational value lies in creating conditions where learners can articulate preliminary ideas, encounter alternative perspectives, and identify relationships that may not emerge through individual reflection. Ball and Christensen (2020) demonstrate how external representations support cognitive and social

processes during creative idea generation, whereas Paulus et al. (2023) emphasize the contribution of collaborative brainstorming to knowledge sharing, associative thinking, and organizational creativity. Puccio et al. (2022) similarly position idea generation within broader creative problem-solving processes that require both divergent and convergent thinking. Empirical support is provided by İnciman Çelik and Akay (2025), whose meta-analysis reported positive effects of brainstorming on academic achievement and creative thinking, although the evidence varied across the included investigations. These findings support the relevance of brainstorming to creative learning while also emphasizing that the quality of implementation matters.

Importantly, brainstorming should not be understood exclusively as an introductory activity intended to generate as many ideas as possible. Creative performance also depends on the ability to recognize promising ideas, combine different perspectives, evaluate feasibility, and revise solutions. Sawyer (2021) characterizes creative work as iterative and improvisational, while Tsai and Hsu (2024) demonstrate the relevance of creative problem-solving activities and reflective discussion to students' creative development. Segundo-Marcos et al. (2023) further identify meaningful relationships between cooperative learning and children's creative thinking, although their educational context differs from university science instruction. Wang et al. (2025) similarly examine the developmental trajectory of creative thinking and intellectual interaction within collaborative learning environments. Together, these studies suggest that sustained opportunities for both divergent and convergent thinking may be more pedagogically valuable than treating brainstorming as a single preparatory exercise. Nevertheless, whether repeatedly structured brainstorming produces additional benefits within project-based science learning requires direct empirical examination rather than theoretical assumption.

This consideration provides the pedagogical rationale for the Project Brainstorming Learning Model (PjBrs-L). The model integrates structured brainstorming into a project-learning sequence in which students repeatedly generate, discuss, evaluate, revise, and communicate ideas. In the present study, PjBrs-L comprises six interconnected stages: brainstorming, designing project steps, project implementation and monitoring, project report and presentation, evaluation, and reflection. During the initial stage, learners identify possible approaches to an authentic scientific problem and articulate alternative ideas. Project planning subsequently requires them to evaluate feasibility, negotiate decisions, and determine appropriate investigative procedures. During implementation, students revisit their initial assumptions and adapt project activities when difficulties or new information emerge. Presentation and evaluation encourage them to communicate their reasoning, respond to feedback, and reconsider the quality of their solutions, while reflection provides opportunities to examine both achievements and unresolved problems. The proposed syntax builds on the documented relationship between project activity, collaborative interaction, and creative problem-solving (Budiarti, 2026; Paulus et al., 2023; Guo et al., 2020). Its distinctive feature is the deliberate recurrence of structured ideation and evaluation across the project cycle, rather than the assumption that conventional PjBL never incorporates such activities.

The integration of brainstorming throughout project learning is also compatible with theoretical accounts of creative cognition. Idea generation involves exploring possible conceptual combinations, while idea evaluation requires identifying constraints, considering evidence, and selecting alternatives suited to the task. These processes are not necessarily sequential in a rigid manner; they may recur as learners encounter difficulties or recognize new opportunities. The instructional logic of PjBrs-L therefore emphasizes an iterative relationship between divergent exploration and convergent judgment. Such an approach is consistent with contemporary scholarship on creative processes and collaborative learning (Sawyer, 2021; Ball & Christensen, 2020; Puccio et al., 2022). Moreover, repeated discussion and project revision may offer opportunities for students to develop confidence through feedback, observational learning, and incremental mastery. This possibility is supported conceptually by Social Cognitive Theory and by empirical studies linking active project experiences with motivational and

efficacy-related outcomes (Bandura, 1997; Schunk & DiBenedetto, 2020; Santos et al., 2025). Nevertheless, these mechanisms should be treated as theoretically plausible rather than as established effects of PjBrs-L because the present investigation did not directly isolate or experimentally test them.

The Indonesian educational context provides further justification for investigating instructional models that connect scientific creativity with active participation. Recent national studies have explored project-based learning through different media, curricular contexts, and learning objectives. Pangestu et al. (2024), for example, examined the relationship between project-based learning, creativity, learning outcomes, and motivation in elementary science instruction. Asnani et al. (2026) developed a project-based biology learning module incorporating local environmental knowledge and reported improvements in students' creative-thinking performance. Although these studies were conducted with school-level participants and employed different instructional materials, they demonstrate the continuing relevance of project-oriented learning within Indonesian science education. Novalia et al. (2025), investigating project-based learning among university students in Indonesia, further identified relationships between project-learning components and students' learning independence. These findings suggest that Indonesian educational research increasingly recognizes the need to examine cognitive and motivational outcomes together. However, they do not directly establish how repeated brainstorming within a specific project-learning syntax relates to creative thinking and academic self-efficacy among prospective science educators.

A related issue concerns the development of reflective and self-regulated learning. Students engaged in complex projects must monitor their progress, evaluate the adequacy of their strategies, and determine whether revisions are necessary. Eshuis et al. (2022) demonstrated the importance of reflection in learning from student-generated concept maps, while Schunk and DiBenedetto (2020) explained the motivational significance of self-regulation and perceived competence. In a broader educational context, Damanik and Remtula (2026) reported positive associations between metacognitive readiness and lifelong learning orientation, although their investigation did not specifically examine project-based science instruction. These perspectives suggest that the reflective elements of PjBrs-L may provide opportunities for students to examine their learning decisions and develop greater awareness of their capabilities. Nevertheless, metacognitive readiness and self-regulation were not separately measured as outcome variables in the present research. Their relevance should therefore remain conceptual rather than being presented as established findings.

The relationship between creative thinking and academic self-efficacy also raises important questions concerning measurement. Creative-thinking performance can be assessed through tasks evaluating the diversity, originality, and elaboration of responses, whereas self-efficacy is commonly measured through judgments of perceived capability. These instruments represent different forms of evidence and should not be treated as interchangeable indicators of educational improvement. Bandura (1997) emphasizes the task-specific nature of efficacy judgments, while Runco and Alabbasi (2024) demonstrate the multidimensional character of divergent-thinking performance. Guo et al. (2020) similarly identify substantial variation in how cognitive and affective outcomes are measured in project-based higher education. Accordingly, an investigation of PjBrs-L must maintain conceptual distinctions between creative-thinking performance, academic self-efficacy, and idea generation. In the present study, creative thinking is conceptualized through fluency, flexibility, originality, and elaboration, while academic self-efficacy refers to students' perceived capability to undertake project-related science-learning tasks. Idea generation represents a related but distinct outcome concerning the production of possible responses and solutions.

Despite the growing literature, important empirical questions remain unresolved. First, existing research provides substantial evidence concerning project-based learning and brainstorming as instructional approaches, but comparatively limited evidence addresses a deliberately structured project-learning model in which brainstorming recurs throughout

planning, implementation, presentation, evaluation, and reflection. Second, previous investigations frequently emphasize a single cognitive or motivational outcome, making it difficult to understand how creative-thinking performance and academic self-efficacy change within the same instructional experience. Third, the relationship between students' perceptions of instructional implementation and their idea-generation performance remains conceptually important but should not be confused with the causal effect of treatment assignment. Finally, systematic reviews indicate that the interpretation of project-based learning outcomes is complicated by differences in instruments, intervention quality, sample characteristics, and research design (Guo et al., 2020; Wijnia et al., 2024; Farshad & Fortin, 2026). Consequently, the need for further investigation concerns not only whether students demonstrate improvement but also how the observed changes and statistical associations can be described without overstating causal certainty.

The novelty of the present study lies in examining PjBrs-L as a specified pedagogical sequence that integrates recurrent brainstorming into project-oriented science learning while investigating creative thinking, academic self-efficacy, and idea generation within the same group of university students. Unlike studies focusing primarily on project outcomes or brainstorming as a discrete activity, the present investigation examines a learning model designed to sustain opportunities for ideation, evaluation, collaborative decision-making, and reflection throughout the project cycle. Its contribution is deliberately framed as preliminary empirical evidence rather than definitive proof of instructional effectiveness. The study employs a one-group pretest–posttest design involving 12 Biology Education undergraduates at Universitas Jambi. Because no comparison group was included, the investigation cannot isolate changes attributable exclusively to PjBrs-L from potential influences such as repeated testing, maturation, or concurrent learning experiences. Moreover, the assessment of idea generation is based on participant-level associations with perceived implementation rather than differences between independently assigned instructional conditions. These methodological boundaries are central to interpreting the contribution appropriately.

Accordingly, this study pursues three objectives. First, it estimates the magnitude and statistical uncertainty of changes in students' creative-thinking scores between pretest and posttest following participation in PjBrs-L. Second, it examines corresponding changes in academic self-efficacy within the same instructional period. Third, it investigates the participant-level association between students' perceptions of PjBrs-L implementation and their idea-generation performance. By addressing these objectives together, the study provides an initial empirical account of cognitive and affective outcomes associated with a structured project-brainstorming sequence in university science education. The findings are expected to inform the refinement of project-oriented instructional design and provide a foundation for subsequent research employing larger samples, comparison groups, and more detailed measures of the learning processes through which creativity and academic self-efficacy may develop.

METHODS

Research Design

The study used a pre-experimental one-group pretest–posttest design. A single group without a comparison condition does not provide the control structure required for strong causal attribution. The design estimates within-participant change, but threats include history, maturation, testing/practice effects, regression to the mean, and concurrent classroom influences. Findings are therefore interpreted as pre–post improvement associated with the intervention period rather than causal effectiveness.

Table 1. One-Group Pretest–Posttest Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2

Note: O_1 = Pretest; X = Project Brainstorming Learning Model; O_2 = Posttest.

Population and Sample

The accessible population for this study was the 12 undergraduate students represented in the selected Biology Education class at Universitas Jambi during the 2025/2026 academic year. All 12 students appear consistently in the supplied pretest and posttest datasets and were included (N = 12). Purposive selection reflected accessibility and relevance to the intended project-based science-learning context. No a priori power analysis was documented in the supplied materials; precision is therefore reported through confidence intervals.

Research Instruments

Creative thinking was assessed with a 21-item performance instrument organized around fluency, flexibility, originality, and elaboration. The supplied validation workbook reports an average expert-validation score of 92% (very feasible). The available files do not contain the full task prompts, item-level scoring rubric, separate rater scores, or inter-rater reliability, so unsupported scoring and reliability details are not claimed.

Data Collection Techniques

Data collection was conducted in three sequential stages: pre-intervention, intervention, and post-intervention. During the pre-intervention stage, students completed the creative thinking test and self-efficacy questionnaire to determine their initial competencies before participating in the learning activities. These pretest data served as the baseline for evaluating the effectiveness of the instructional intervention. The intervention stage consisted of six learning meetings implementing the Project Brainstorming Learning Model. Throughout the learning process, students participated in authentic problem orientation, collaborative brainstorming, idea selection and planning, project development, presentation, and reflection activities. Simultaneously, classroom observations were conducted by two independent observers to monitor the consistency of model implementation and students' participation throughout each learning phase. During the post-intervention stage, students completed the same creative thinking test and self-efficacy questionnaire as posttests to measure learning improvement. In addition, students' idea generation performance during brainstorming activities was documented and analyzed to examine its relationship with the implementation of the Project Brainstorming Learning Model.

The study adhered to the ethical principles of educational research. Permission to conduct the research was obtained from the Biology Education Study Program, Universitas Jambi, prior to data collection. Participation was voluntary, and all students received information regarding the objectives and procedures of the study before providing informed consent. Participants' anonymity and confidentiality were maintained throughout the research process, and all collected data were used exclusively for academic purposes.

Data Analysis Techniques

Descriptive statistics included mean, SD, minimum–maximum, and 95% confidence intervals. Normality was evaluated on paired difference scores using Shapiro–Wilk. Paired-sample t-tests estimated mean change, with dz as the standardized paired effect size. Wilcoxon signed-rank tests were calculated as sensitivity analyses. Regression used the participant-level PjBrs-L implementation-perception total as predictor and idea-generation total as criterion. Diagnostics included residual normality, homoscedasticity, leverage, and Cook’s distance.

Research Ethics

This study adheres to ethical principles of educational research. Permission to conduct the study was obtained from the participating schools prior to data collection. Students participated voluntarily after receiving information about the study's purpose and procedures. Participants' anonymity and confidentiality were maintained throughout the research process, and all data collected was used exclusively for academic purposes.

RESULT AND DISCUSSION

Results

The results are organized according to the three research objectives: (1) estimating the magnitude and uncertainty of pre-post change in creative thinking, (2) estimating the magnitude and uncertainty of pre-post change in academic self-efficacy, and (3) examining the participant-level association between perceived PjBrs-L implementation and idea generation. All 12 participants completed both pretest and posttest assessments. Prior to paired comparisons, normality was examined using Shapiro-Wilk tests on the paired difference scores. No strong departure from normality was detected for creative thinking ($W = .965$, $p = .847$) or self-efficacy ($W = .938$, $p = .470$), supporting the use of paired-sample t-tests for the primary analyses.

Pre-Post Change in Students' Creative Thinking

The first research objective was to estimate the magnitude and uncertainty of the change in students' creative-thinking scores between the pretest and posttest. As shown in Table 2, the mean creative-thinking score increased from 78.17 at pretest to 85.92 at posttest, corresponding to an average increase of 7.75 points. The paired-sample t-test indicated that this within-participant difference was statistically significant, $t(11) = -6.632$, $p < .001$. The 95% confidence interval for the mean change ranged from 5.18 to 10.32 points, indicating that the observed increase was consistently positive within the sample. The standardized paired effect size was large, $dz = 1.91$.

Table 2. Pre-Post Change in Creative Thinking

Measure	N	Pre M	Post M	Mean diff.	95% CI	t(11)	p	dz
Creative thinking	12	78.17	85.92	7.75	[5.18, 10.32]	-6.632	< .001	1.91

Note. Positive mean difference represents an increase from pretest to posttest. Because the study employed a one-group pretest-posttest design, the statistic represents within-participant change during the study period rather than a causal treatment effect.

The descriptive and inferential results directly address the first objective by providing the magnitude of change, confidence interval, statistical significance, and standardized effect size. The analysis was based on the total creative-thinking score. Although the instrument addressed fluency, flexibility, originality, and elaboration, the available dataset contained total scores rather than separate dimension-level results; consequently, no claim is made regarding which component of creative thinking changed most.

Pre-Post Change in Students' Academic Self-Efficacy

The second objective examined the magnitude and uncertainty of pre-post change in academic self-efficacy. Students obtained a mean self-efficacy score of 79.50 before participating in the PjBrs-L learning sequence and 85.75 at posttest, resulting in an average increase of 6.25 points. The paired comparison was statistically significant, $t(11) = -8.567$, $p < .001$. The estimated mean difference had a 95% confidence interval of [4.64, 7.86], while the standardized paired effect size was $dz = 2.47$, indicating a substantial within-participant difference in this sample.

Table 3. Pre-Post Change in Academic Self-Efficacy

Measure	N	Pre M	Post M	Mean diff.	95% CI	t(11)	p	dz
Academic self-efficacy	12	79.50	85.75	6.25	[4.64, 7.86]	-8.567	< .001	2.47

Note. Self-efficacy refers to academic self-efficacy contextualized to project-based science learning. The reported statistic represents pre-post change within the same participants and should not be interpreted as evidence of causal effectiveness in the absence of a comparison group.

These results answer the second research objective by quantifying both the size and precision of the observed change in students' academic self-efficacy. The posttest mean exceeded the pretest mean by 6.25 points, and the confidence interval did not include zero. As with creative

thinking, however, the result represents change observed during the intervention period rather than an experimentally isolated treatment effect because possible influences such as maturation, repeated testing, history, or concurrent learning experiences were not controlled.

Association Between Perceived PjBrs-L Implementation and Idea Generation

The third research objective was to examine the participant-level relationship between perceived implementation of PjBrs-L and students' idea-generation scores. Importantly, the regression predictor was not treatment assignment, because all 12 students participated in PjBrs-L. Instead, the predictor was each participant's five-item PjBrs-L implementation-perception total, which ranged from 18 to 24, while the criterion variable was the five-item idea-generation total, ranging from 16 to 24.

The regression analysis revealed a very strong positive association between the two participant-level measures, R = .991, R^2 = .981, adjusted R^2 = .980, F(1, 10) = 527.55, p < .001. The unstandardized regression coefficient was positive, B = 1.194, 95% CI [1.078, 1.310], with t = 22.968. Thus, higher perceived implementation scores were associated with higher idea-generation scores within this sample.

Table 4. Regression of Idea Generation on Perceived PjBrs-L Implementation

Predictor	R	R^2	Adj. R^2	B	95% CI for B	t	F(1,10)	p
PjBrs-L perception	.991	.981	.980	1.194	[1.078, 1.310]	22.968	527.55	< .001

Note. The predictor represents individual participants' implementation-perception scores, not intervention assignment. Consequently, R^2 represents the proportion of variance shared statistically between the two participant-level measures and should not be interpreted as the percentage of idea generation caused by PjBrs-L.

Regression diagnostics did not indicate a strong departure from residual normality, Shapiro-Wilk W = .940, p = .497, and the Breusch-Pagan test did not indicate heteroscedasticity, p = .932. However, the maximum Cook's distance was 1.017, indicating the presence of an influential observation. Accordingly, the exceptionally high correlation and explained variance should be reported as a strong association within the present dataset, rather than as a stable population-level effect or evidence that PjBrs-L caused 98.1% of students' idea-generation performance.

Overall, the three analyses directly address the stated research objectives. The first two analyses quantify the magnitude and uncertainty of pre-post changes in creative thinking and academic self-efficacy, while the third examines the participant-level association between perceived PjBrs-L implementation and idea generation. The results are therefore presented as observed within-participant changes and statistical associations, not as definitive causal effects.

Discussion

The findings provide preliminary evidence of substantial within-participant improvement in creative thinking and self-efficacy and a strong participant-level association between PjBrs-L implementation perception and idea generation. Because the study has no comparison group, the findings should be interpreted as observed change rather than definitive causal effectiveness. The significant improvement in students' creative thinking can be explained through theories of creativity emphasizing divergent thinking, originality, flexibility, fluency, and elaboration as core dimensions of creative performance. During brainstorming, students were encouraged to generate multiple alternative ideas without immediate criticism, reflecting fundamental brainstorming principles. The iterative process of generating, discussing, and refining ideas also aligns with Creative Cognition Theory, which argues that creativity develops through continuous cycles of idea generation and exploration (Ball & Christensen, 2020; Choi et al., 2026; Sawyer, 2021). These findings suggest that systematic brainstorming serves as an effective cognitive scaffold that enables students to produce more original and meaningful scientific ideas.

The increase in students' self-efficacy further supports Bandura's Social Cognitive Theory, which states that self-efficacy develops through mastery experiences, social interaction, verbal

encouragement, and successful task completion (Bandura, 1997). Throughout the Project Brainstorming Learning Model, students repeatedly proposed ideas, received peer feedback, revised project designs, and successfully completed authentic scientific projects. These learning experiences strengthened students' confidence in solving scientific problems and making collaborative decisions. The findings therefore extend previous evidence that project based learning promotes students' confidence by demonstrating that continuous brainstorming embedded within every project stage further reinforces self-efficacy through sustained collaboration and reflective learning (Santos et al., 2025). Another important finding is the strong relationship between the learning model and students' idea generation. This result confirms that brainstorming functions as the primary pedagogical mechanism underlying creativity during project implementation. According to Puccio et al. (2022), idea generation represents the foundation of creative problem solving because innovative solutions emerge from producing diverse and meaningful alternatives. Similarly, Paulus et al. (2023) argued that collaborative brainstorming stimulates cognitive activation, knowledge sharing, and associative thinking that enhance creative performance. The present findings therefore indicate that systematically integrating brainstorming throughout project activities substantially strengthens students' ability to generate innovative ideas rather than limiting creativity to the initial planning stage.

Compared with previous studies, this research extends the literature in several ways. Earlier investigations generally examined Project Based Learning and brainstorming independently or focused primarily on academic achievement, critical thinking, or problem-solving skills (Al-Thani & Ahmad, 2025; Bonnardel & Didier, 2020; Hizqiyah et al., 2023). In contrast, the present study integrates brainstorming into a structured project learning syntax and simultaneously evaluates three complementary learning outcomes: creative thinking, self-efficacy, and idea generation. This integrated perspective provides a more comprehensive understanding of how instructional design influences both cognitive and affective learning outcomes. The principal novelty of this study lies in the development of the Project Brainstorming Learning Model, which positions brainstorming as a structured instructional syntax implemented throughout the entire project cycle from brainstorming, project planning, project implementation and monitoring, project presentation, evaluation, to reflection (Budiarti, 2026). Unlike conventional Project Based Learning, where brainstorming typically occurs only at the beginning of instruction, the proposed model continuously facilitates idea generation, collaborative evaluation, reflection, and project refinement. This continuous process creates repeated opportunities for creative exploration and knowledge reconstruction, thereby supporting students' creativity, confidence, and innovative thinking simultaneously.

The findings have important implications for science education. Theoretically, they strengthen constructivist and social cognitive perspectives by demonstrating that structured brainstorming simultaneously supports cognitive development and affective growth. Practically, science teachers should integrate brainstorming throughout project implementation rather than using it solely as an introductory activity. Such integration encourages students to actively explore ideas, justify scientific reasoning, collaborate effectively, and develop greater confidence in addressing authentic scientific problems, all of which represent essential competencies for twenty-first-century learning. Despite these promising findings, several limitations should be considered. The study involved a relatively small sample from a single school and employed a one-group pretest-posttest design, limiting the generalizability and causal interpretation of the results. Furthermore, only quantitative data were collected, leaving students' learning experiences insufficiently explored. Future studies should involve larger and more diverse samples, include comparison groups, adopt mixed-method approaches, and examine the long-term effects of the Project Brainstorming Learning Model on broader twenty-first-century competencies, including collaboration, communication, innovation, and scientific literacy.

CONCLUSION

This study examined changes in students’ creative thinking and academic self-efficacy following

the implementation of the Project Brainstorming Learning (PjBrs-L) model and investigated the relationship between perceived model implementation and idea generation in higher education science learning. The findings revealed statistically significant improvements in both cognitive and affective outcomes following six instructional sessions. Creative-thinking scores increased from 78.17 to 85.92, representing a mean improvement of 7.75 points, $t(11) = -6.632$, $p < .001$, with a large standardized effect size ($dz = 1.91$). Similarly, academic self-efficacy increased from 79.50 to 85.75, with a mean improvement of 6.25 points, $t(11) = -8.567$, $p < .001$, and a substantial effect size ($dz = 2.47$). Furthermore, regression analysis identified a strong positive association between perceived PjBrs-L implementation and students' idea generation ($R = .991$, $R^2 = .981$, $p < .001$). Collectively, these findings indicate substantial within-participant improvements and a strong relationship between students' perceptions of the learning model and their idea-generation performance. The results provide preliminary empirical support for investigating structured brainstorming as a recurring component of project-based science learning, while recognizing that the observed improvements cannot be attributed exclusively to the intervention.

Theoretically, this study contributes to constructivist learning and Social Cognitive Theory by providing preliminary evidence consistent with the role of collaborative idea generation, reflective learning, and mastery-oriented experiences in supporting creative thinking and academic self-efficacy. Pedagogically, the PjBrs-L model offers a structured approach through which educators can incorporate brainstorming into project planning, implementation, presentation, evaluation, and reflection rather than restricting it to initial idea generation. Nevertheless, the study involved only 12 undergraduate students from a single university class and employed a one-group pretest–posttest design without a comparison condition, limiting causal inference and generalizability. The exceptionally strong regression association also requires cautious interpretation because an influential observation was identified. Future research should employ larger, multisite samples, controlled or randomized comparative designs, and longitudinal assessments to establish the model's relative effectiveness, examine its underlying mechanisms, and evaluate the sustainability of creative-thinking and self-efficacy development. Ultimately, this study provides a foundation for further investigation of systematically integrated brainstorming as a pedagogical strategy for fostering creativity, confidence, and meaningful participation in science education.

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