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Comparing PJBL and PJBL-STEM Models in Enhancing Students' Creativity in Continental Cuisine Processing at the Vocational Education Level

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ABSTRACT

This study investigates the comparative impact of Project-Based Learning (PjBL) and STEM-integrated Project-Based Learning (PjBL-STEM) on students' creativity in continental food processing classes among 12th-grade culinary students at SMK N 1 Bawen. Employing a quasi-experimental design with a non-equivalent control group pretest-posttest structure, the study involved a sample of 72 students selected through simple random sampling from a total population of 108. Data were collected using structured classroom observation instruments, which were validated through expert judgment and demonstrated strong content validity and reliability (Cronbach's Alpha > 0.80). The data analysis was conducted using independent samples t-test, preceded by normality and homogeneity testing. The results revealed a statistically significant difference in creativity between the two groups ($p = .001$), indicating that the PjBL-STEM model led to superior learning outcomes. Students taught using the PjBL-STEM model achieved a higher average post-test score ($M = 76.03$) compared to those taught using PjBL alone ($M = 69.11$). These findings suggest that integrating STEM into project-based learning effectively enhances students' creativity in vocational culinary education, offering promising implications for instructional design in 21st-century skills development.

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1. INTRODUCTION

In the modern era of globalization, education plays a pivotal role in shaping the quality of human resources capable of navigating rapid technological advancement and complex societal challenges. The transformation of education must therefore emphasize the development of 21st-century skills, which include critical thinking, creativity, collaboration, and communication, collectively known as the 4Cs (Johan et al., 2020; (Redhana, 2019; Thornhill-Miller et al., 2023). Among these, creativity is regarded as a core competence essential not only for innovation but also for fostering personal expression, problem-solving abilities, and adaptive thinking in dynamic environments (Gube & Lajoie, 2020; Munandar, 2006).

The Indonesian government has initiated curricular reforms aligned with these global educational demands, as embodied in the Merdeka Curriculum, which encourages learner autonomy, creativity, and contextualized knowledge application. This initiative is rooted in the national education mandate, as outlined in Law No. 20 of 2003, which affirms that education functions to develop human potential and shape a dignified national civilization (Salma, 2017). Additionally, the Ministry of Education and Culture (2016) emphasizes that high school graduates must demonstrate skills in critical thinking, independence, productivity, collaboration, and communication (Firmantara et al., 2023).

However, despite these policy directives, pedagogical practice at the vocational high school level, particularly in the Culinary Arts Department (Tata Boga), remains predominantly teacher-centered. At SMK Negeri 1 Bawen, for example, the Continental Food Processing course is still delivered mainly through lectures and question-and-answer sessions, with minimal integration of technology or interactive learning methods. As a result, students tend to be passive, and their motivation, learning outcomes, and creativity remain suboptimal, particularly in subjects that demand hands-on, practical engagement.

Creativity in culinary education is not merely an abstract construct but a tangible skill demonstrated in students' ability to innovate, adapt, and aesthetically express their ideas through food presentation. As Hastowati (2019) argues, creative behavior in food processing reflects students' mastery of both theoretical and practical dimensions of learning. Hence, a pedagogical shift is needed to bridge this gap and foster creativity through active, student-centered learning strategies.

One promising approach is Project-Based Learning (PjBL), which centers on complex tasks that culminate in the creation of a product or performance. PjBL encourages learners to engage in sustained inquiry, collaboration, and reflection, key components that stimulate higher-order thinking and real-world problem-solving skills (Loyens et al., 2023; Rahayu et al., 2017; Vidergor & Krupnik-Gottlieb, 2015). Yet, the effectiveness of PjBL can be significantly enhanced when it is integrated with the STEM framework, comprising Science, Technology, Engineering, and Mathematics, thus forming the PjBL-STEM model.

The PjBL-STEM approach provides students with opportunities to explore interdisciplinary concepts and apply them through an engineering design process. This model emphasizes iterative thinking, innovation, and experimentation, critical elements in culinary education where learners must not only follow recipes but also develop novel food products, improve preparation methods, and respond to practical constraints (Fitriyani et al., 2020; Heryuriani & Musdayati, 2020; Sharif et al., 2024). According to Mulyani (2019), integrating STEM into vocational education enables students to see how theoretical principles are applied to solve everyday problems in meaningful and creative ways.

Moreover, the inclusion of technology and information tools into PjBL-STEM pedagogy

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enriches the learning process by broadening students' access to knowledge and enhancing their digital literacy. This is particularly crucial in the context of vocational schools, where proficiency in using digital media and kitchen technologies is increasingly valued in the job market. However, based on recent findings, such integration remains minimal at SMK N 1 Bawen, where the use of instructional media and technological tools is still underdeveloped, resulting in poor student engagement and comprehension of continental food processing concepts.

To address these challenges, this study proposes a comparative analysis of PjBL and PjBL-STEM models in improving student creativity in the Continental Food Processing course for Grade XII Culinary Arts students at SMK N 1 Bawen. Creativity, in this study, is conceptualized as the ability to produce original, contextually relevant, and aesthetically pleasing culinary outputs. The study seeks to answer the following research question: To what extent does the integration of STEM into project-based learning improve student creativity compared to PjBL alone?

This investigation is significant for several reasons. First, it addresses a notable gap in the literature, as few empirical studies have examined the integration of PjBL and STEM in the context of Indonesian vocational education, especially in culinary programs. Second, the study offers practical implications for teachers and curriculum developers seeking to improve the effectiveness of teaching strategies through interdisciplinary learning. Lastly, it contributes to broader educational discourse by showcasing how creative competencies can be fostered through pedagogical innovation in non-STEM-exclusive disciplines.

The PjBL-STEM model, as conceptualized by Laboy-Rush, incorporates five main phases: reflection, research, discovery, application, and communication, each designed to guide students through a structured problem-solving process (Afriana et al., 2016; Nida et al., 2023). In culinary contexts, this sequence enables learners to identify problems in food preparation, conduct background research, experiment with ingredients and techniques, test their outcomes, and present their findings, thereby integrating scientific and creative processes in authentic learning environments.

Ultimately, this study aims to contribute to the transformation of vocational education in Indonesia by advocating for innovative, interdisciplinary learning models that prepare students not only for academic success but also for the demands of the modern culinary industry. By exploring the comparative impacts of PjBL and PjBL-STEM on student creativity, the research provides valuable insights into how instructional design can empower learners to become independent, innovative, and reflective practitioners in their chosen fields.

2. METHOD

2.1 Research Design

This study employed a quasi-experimental design, specifically the non-equivalent control group pretest–posttest design. In quasi-experimental research, participants cannot be randomly assigned to experimental conditions because intact groups already exist prior to the study. Such designs are widely used and considered appropriate in educational research, where random assignment is often impractical or impossible (Hasnunidah, 2017).

Two intact classes of Grade XII Culinary Arts students at SMK Negeri 1 Bawen were selected as the research sample. One class was assigned to the PjBL treatment group, and the other to the PjBL-STEM treatment group, allowing comparison of the instructional interventions on students' creativity in continental food processing. The study was conducted during the second semester of the 2023/2024 academic year at SMK N 1 Bawen, located in

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Semarang Regency, Central Java, Indonesia.

The population consisted of 108 Grade XII students enrolled in the Culinary Arts program. A probability sampling technique was used to ensure equal selection opportunity for each population member. The selection of classes for participation was carried out using simple random sampling, where the names of three available classes (XII-A, XII-B, XII-C) were written on paper, rolled, and drawn randomly (Sugiyono, 2019).

2.2 Data Collection Technique

Data on student creativity in continental food processing were collected using a structured observation sheet developed by the researcher. The instrument was designed to assess three key dimensions of creativity: originality, problem-solving ability, and elaboration. Originality referred to students' capacity to generate unique culinary ideas, problem-solving captured their ability to apply knowledge effectively during food preparation, and elaboration reflected their skills in refining and aesthetically enhancing food products.

To establish validity, the instrument underwent expert judgment involving specialists in culinary education who evaluated the relevance, clarity, and coverage of each item. Their input was used to revise the instrument accordingly. The level of agreement among experts was quantified using Aiken's V, with items considered valid if the V value exceeded the critical threshold (Azwar, 2018). Instrument reliability was confirmed using Cronbach's Alpha to ensure internal consistency, with a high coefficient indicating that the instrument was dependable for repeated use.

2.3 Data Analysis Technique

Before conducting hypothesis testing, assumption checks were performed to ensure data met the criteria for parametric analysis. These included tests for normality to examine the distribution of creativity scores and homogeneity to verify equal variances across groups. Meeting these assumptions was essential for the accuracy of the subsequent statistical tests.

The main analysis employed an independent samples t-test to compare the mean creativity scores between the PjBL and PjBL-STEM groups. This test determined whether the integration of STEM elements into project-based learning led to a statistically significant improvement in student creativity. A significance level of $p < .05$ was used to decide whether to reject the null hypothesis, providing evidence for the effectiveness of the instructional intervention.

3. RESULT AND DISCUSSION

3.1 Result

This study began with the validation of research instruments, including the creativity rubric, instructional model instruments, and the learning design. Two subject matter experts evaluated the creativity rubric using a scoring rubric across indicators of originality, problem-solving, and elaboration. As shown in Table 1, Expert I assigned a total score of 81 (84.4%), while Expert II assigned a score of 87 (90.6%). Both assessments fall into the "very good" category, indicating that the creativity instrument met the necessary criteria for validity in measuring student performance in continental food processing.

Table 1. Expert Validation Results for Student Creativity Instrument

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Dimension	Indicator Description	Expert I	Expert II
Originality	Multiple continental ingredients used	3	4
	Uses multiple cooking techniques	3	4
	Multiple cutting techniques	4	3
	Multiple presentation types	3	4
	Multiple condiment use	4	3
	Novel combination of flavors	3	4
	Multiple textures applied	4	3
Problem-Solving	Good flavor criteria met	3	4
	Good appearance, aroma, equipment	3	4
	Correct portion size	4	3
	Balanced nutrition composition	3	4
	Ease of consumption	3	4
Elaboration	Artistic food arrangement	3	4
	Marketability of dish	4	3
	Harmony with garnish and tools	4	3
	Correct portioning	4	3
	Variety of presentations	4	3
	Attractive focal point	3	4
	Proper plate layout	3	4
	Clean and attractive tools	3	4
	Garnish variety and hygiene	4	3
	Main dish is dominant	3	4
	Garnish–tool harmony	3	4
	No repetition of ingredients/colors	3	4
Total Score		81	87
Percentage		84.40%	90.60%
Category		Very Good	Very Good

The validation of the instructional model instrument also resulted in high scores. As shown in Table 2, Expert I assigned a total score of 41 (85.4%), and Expert II assigned 43 (89.6%), again falling into the "very good" category. This validates the alignment of the model (both PjBL and PjBL-STEM) with competency indicators and 21st-century learning objectives.

Table 2. Expert Validation Results for Instructional Model Instrument

Aspect	Criteria	Expert I	Expert II
Content	Alignment with IPK	4	3
	Learning objectives	3	4
	Creativity relevance	4	3
	Content depth	3	4
	Concept accuracy	4	3
PJBL	PJBL model in RPP	3	4
	PJBL syntax alignment	3	4
PJBL-STEM	PJBL-STEM model in RPP	4	3
	PJBL-STEM syntax	3	4
Language	Sentence clarity	3	4

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Aspect	Criteria	Expert I	Expert II
	Language clarity	3	4
	Grammar standards	4	3
Total Score		41	43
Percentage		85.40%	89.60%
Category		Very Good	Very Good

Validation of the learning implementation plan (RPP) was also rated “very good” by both experts, with scores of 88.0% and 87.0%, as shown in Table 3.

Table 3. Expert Validation Results for Lesson Plan Instrument

Component	Indicators	Expert I	Expert II
	Culturally relevant objectives	4	3
	Context-based learning model	3	4
Planning	Use of project/inquiry model	4	3
	Local culture in scenario	3	4
	Critical thinking opportunity	4	3
	Teacher–student collaboration	3	4
Implementation	Learning outcomes formulation	3	4
	Culture as learning material	4	3
	Diagnostic assessment	3	4
	Learner profiling	3	4
	Pancasila student profile	3	4
	Learning target formulation	4	3
	Chosen model clarity	4	3
	Learning goal clarity	4	3
	Assessment of/as/for learning	3–4	3–4
	Essential understanding	3	4
	Trigger questions	4	3
	Activity suitability	4	3
	Student worksheet design	4	3
	Enrichment/remediation	4	3
	Student reading material	3	4
Total		81	80
Percentage		88.00%	87.00%
Category		Very Good	Very Good

Instrument validity was also confirmed using Aiken’s V formula. All items in the creativity rubric achieved a V value of 0.833, which exceeds the critical threshold (0.800). Reliability testing using Cronbach's Alpha confirmed high internal consistency across all instruments, with values ranging from 0.809 to 0.848, as shown in Table 4. The creativity instrument scored highest at 0.848. Further reliability testing of the try-out questionnaire yielded $\alpha = 0.963$.

Table 4. Instrument Reliability Results

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Variable	Cronbach Alpha	Interpretation
Creativity	0.848	High
Instructional Model	0.809	High
PJBL-STEM Instrument	0.817	High
PJBL Instrument	0.823	High

All individual item validity coefficients for the creativity instrument also exceeded the r-table value of 0.3, confirming each item's statistical validity. Creativity scores of students in the PJBL-STEM group increased significantly after treatment. Table 5 shows that before the intervention, only 22.2% were in the "very creative" category, which rose to 61.1% after treatment (Table 6).

Table 5. Pre-test Creativity – PJBL-STEM Group

Category	Score Range	Frequency	Percentage
Very Creative	X ≥ 72.00	8	22.20%
Creative	60.00 ≤ X < 72.00	12	33.30%
Less Creative	48.00 ≤ X < 60.00	6	16.70%
Not Creative	X < 48.00	10	27.80%

Table 6. Post-test Creativity – PJBL-STEM Group

Category	Score Range	Frequency	Percentage
Very Creative	X ≥ 72.00	22	61.10%
Creative	60.00 ≤ X < 72.00	14	38.90%
Less Creative	48.00 ≤ X < 60.00	0	0.00%
Not Creative	X < 48.00	0	0.00%

In the PJBL group, the percentage of "very creative" students increased from 27.8% (Table 12) to 41.7% after intervention (Table 7).

Table 7. Pre-test Creativity – PJBL Group

Category	Score Range	Frequency	Percentage
Very Creative	X ≥ 72.00	10	27.80%
Creative	60.00 ≤ X < 72.00	11	30.60%
Less Creative	48.00 ≤ X < 60.00	7	19.40%
Not Creative	X < 48.00	8	22.20%

Table 8. Post-test Creativity – PJBL Group

Category	Score Range	Frequency	Percentage
Very Creative	X ≥ 72.00	15	41.70%
Creative	60.00 ≤ X < 72.00	16	44.40%
Less Creative	48.00 ≤ X < 60.00	5	13.90%
Not Creative	X < 48.00	0	0.00%

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Assumption tests using Kolmogorov–Smirnov and Levene's Test confirmed normal data distribution and homogeneity of variance. All significance values exceeded 0.05.

Table 9. Normality Test Results

Group	Test	Sig. Value	Conclusion
PJBL-STEM Pretest	K-S	0.121	Normal
PJBL-STEM Posttest	K-S	0.141	Normal
PJBL Pretest	K-S	0.2	Normal
PJBL Posttest	K-S	0.2	Normal

Table 10. Homogeneity Test (Levene's Test)

Variable	Sig. Value	Conclusion
Pretest	0.876	Homogeneous
Posttest	0.776	Homogeneous

An independent samples t-test confirmed a significant difference between groups, with $p = 0.001 < 0.05$ (Table 11). The mean creativity score for the PJBL-STEM group (76.03) was higher than that of the PJBL group (69.11), as shown in Table 12.

Table 11. Independent Samples T-Test Result

Sig. (2-tailed)	Mean Difference	Conclusion
0.001	6.92	Significant

Table 12. Post-test Mean Comparison

Group	Mean Score
PJBL-STEM	76.03
PJBL	69.11

3.2 Discussion

The findings of this study reveal that the integration of STEM within the PjBL framework significantly enhances student creativity in vocational education, particularly in the field of continental food processing. Students who participated in the PjBL-STEM model demonstrated more advanced creative capacities than those in the conventional PjBL group. This difference is evidenced not only in the statistical analysis, which confirmed the significance of the instructional effect, but also in the observed shifts in creativity levels as measured across dimensions such as originality, problem-solving, and elaboration.

One of the key mechanisms underlying the superiority of the PjBL-STEM approach lies in its multidimensional structure. Unlike traditional instruction or even basic project-based learning, the STEM-integrated model offers learners a structured yet flexible environment in which to explore problems, apply interdisciplinary knowledge, and design solutions with tangible outcomes. The engineering design process embedded in STEM learning encourages students to iterate, test, and improve their outputs, mirroring the process of culinary

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innovation in professional practice. Through this iterative process, students are not only absorbing knowledge but transforming it into creative products that reflect individual expression, technical proficiency, and contextual relevance (Fitriyah & Ramadani, 2021; Henriksen et al., 2016).

This finding affirms the theoretical perspective that creativity is not a fixed trait but a dynamic cognitive and affective process that can be fostered through appropriate pedagogical interventions. The constructivist foundations of PjBL-STEM support active learning, where students construct knowledge through exploration and application rather than passively receiving information. In vocational settings such as culinary education, where tactile engagement, sensory analysis, and aesthetic judgment are integral to learning, this model is particularly relevant. The context-rich nature of culinary tasks, requiring adaptation, improvisation, and decision-making, aligns seamlessly with the goals of STEM education, which emphasizes inquiry, innovation, and real-world problem solving (Afriana et al., 2016).

Furthermore, this study's results corroborate a growing body of literature that underscores the effectiveness of STEM-integrated project learning in cultivating creative and critical thinking. Prior research has demonstrated that STEM-based learning environments promote deeper cognitive engagement and foster a capacity for original thought across diverse educational contexts. Studies by Sukmawijaya et al. (2019) and Siskawati et al. (2020) highlight that STEM and PjBL models, when implemented together, create synergies that lead to measurable gains in creative competencies. Similarly, Fitriyah & Ramadani (2021) found that STEAM-based PjBL models significantly influenced students' creative expression in artistic and applied fields. The findings from this study align closely with these insights, particularly in validating the transferability of the PjBL-STEM model into vocational domains such as gastronomy.

The integration of STEM also reflects broader pedagogical goals in 21st-century education, particularly the development of students' capacity to function as innovative problem solvers in complex, unpredictable environments. In culinary education, this translates to the ability to conceptualize, prepare, and present dishes that are not only technically correct but also creatively distinctive. By encouraging students to engage with scientific principles, technological tools, and mathematical reasoning within the context of food production, the PjBL-STEM model elevates the learning experience from routine skill acquisition to innovative practice (Becker & Park, 2011; Nastiti et al., 2024).

Beyond individual skill development, the model promotes collaborative learning, communication, and reflective thinking. These outcomes are central to the holistic development of vocational learners, who must navigate not only technical demands but also teamwork, client interaction, and adaptive learning in their professional roles. Through projects that mimic real-world scenarios, students learn to collaborate effectively, manage time and resources, and make informed decisions, all of which contribute to the creative process. The pedagogical strength of PjBL-STEM thus lies in its ability to activate multiple domains of student intelligence and agency in a cohesive learning structure (Kussudarto & Rosdiana, 2024; Redhana, 2019).

From a curriculum development perspective, the findings of this study underscore the importance of designing learning experiences that integrate content knowledge with hands-on, interdisciplinary inquiry. Traditional vocational instruction, which often prioritizes technical repetition and routine performance, can limit the potential for student creativity to emerge. The PjBL-STEM model provides a pathway to reframe vocational education as intellectually rigorous and creatively generative, thereby aligning it with contemporary

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educational imperatives and labor market expectations (Mulyani, 2019; Wati et al., 2024). It demonstrates that vocational students are not only capable of high-order creative thinking but can thrive when offered the right pedagogical conditions to do so (Sukarma et al., 2024).

In essence, this study supports the view that instructional models grounded in interdisciplinary design and authentic learning tasks can serve as powerful catalysts for creative development. The findings provide empirical validation for PjBL-STEM as an instructional strategy that enhances creativity in ways that are measurable, meaningful, and directly applicable to students' future professional contexts. By combining the depth of STEM disciplines with the agency and engagement of project-based learning, this model offers a compelling framework for educational innovation in both academic and vocational settings.

4. CONCLUSION

This study provides clear evidence that integrating STEM components into project-based learning significantly enhances students' creativity in vocational culinary education. The PjBL-STEM model consistently produced higher creativity outcomes than the conventional PjBL approach, as demonstrated by the statistically significant differences in post-test scores. Through interdisciplinary engagement and iterative design processes, students were able to transform conceptual knowledge into innovative culinary products, reinforcing the value of STEM-oriented project learning in advancing originality, elaboration, and real-world problem-solving skills. These findings affirm the potential of PjBL-STEM as a powerful pedagogical framework for developing 21st-century competencies essential for vocational learners navigating increasingly complex professional environments.

Although the study offers strong empirical support for the effectiveness of PjBL-STEM, several limitations warrant consideration. The research was conducted at a single school and focused specifically on continental food processing, which may limit the generalizability of the findings to other vocational contexts or culinary domains. The study also relied primarily on quantitative measures, which, while robust, do not capture students' subjective experiences or the nuanced dynamics of classroom engagement. Future research is recommended to expand the scope across multiple institutions, incorporate mixed-method approaches to deepen understanding of learner responses, and explore long-term impacts of PjBL-STEM on professional readiness, creativity sustainability, and workplace performance. Such efforts will strengthen the theoretical and practical foundations of STEM-integrated project learning within vocational education and beyond.

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