Indonesian Journal of Educational Research and Technology

Implementation of the STEM-Based Project-Based Learning (PjBL) Model to Enhance Students' Critical Thinking and Creativity in Fusion Food Materials

Adhi Setyobudi[*], Herminarto Sofyan, Kokom Komariah

Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[*]Correspondence: E-mail: Adhisetyobudi.2022@student.uny.ac.id

A B S T R A C T

This study aims to determine the effect of the STEM-based PJBL learning model on students' critical thinking skills and creativity. This study is a quasi-experimental study with quantitative methods. The study design uses a nonequivalent control group design. The population in this study were 108 students of class XII Culinary Arts at SMK N 1 Bawen in the 2024/2025 academic year. The sampling technique used was proportionate random sampling, obtaining 72 students. Data collection used tests, observations, and questionnaires. The data analysis technique used the MANOVA test. The results of the study show that: (1) there is an effect of the PJBL learning model with STEM on students' critical thinking skills, (2) there is an effect of the PJBL learning model with STEM on students' creativity, (3) there is a difference in critical thinking skills between students taught with PJBL learning with STEM and students taught with conventional PJBL learning, and (4) there is a difference in student creativity towards conventional learning models and PJBL-STEM.

A R T I C L E   I N F O

1. INTRODUCTION

Education is a fundamental need that must be fulfilled in the course of life. Education in the modern era plays a crucial role in the development of a nation in facing the challenges and technological advancements of the 21st century global era. At present, education should be able to foster 21st-century skills, including technological and informational literacy, collaborative skills, and communicative skills. When communicative abilities are instilled and developed in students, they will become human resources capable of expressing themselves with greater confidence.

The National Education Association has identified 21st-century skills as the "4Cs," which include critical thinking, creativity, communication, and collaboration (Redhana, 2019). Creative thinking skills are an important part of 21st-century competencies to be developed in education, as they train students to generate ideas, express opinions, and acknowledge the validity of arguments. In turn, students will develop self-confidence and responsibility as citizens.

Critical thinking skills are also essential for students' cognitive development. They enable students to adapt to the rapid advancements of the modern era. With the abundance of innovations and new information, students are required to possess a high level of critical thinking ability. According to data from the Programme for International Student Assessment (PISA), Indonesian students' critical thinking skills remain relatively low (Natassya *et al.*, 2023). This is consistent with Indonesia's PISA results, which showed a decline in education scores in 2018 and 2022 compared to 2015. In 2022, PISA reported a global decline in academic achievement, influenced by the COVID-19 pandemic. Nevertheless, Indonesia's ranking in PISA 2022 rose by 5–6 positions compared to 2018. However, from 2000 to 2022, Indonesia consistently ranked among the bottom ten countries in scientific literacy in PISA assessments (Yusmar & Fadilah, 2023). This reflects the low level of higher-order critical thinking skills among students aged 15 and above.

Several efforts have been implemented, such as reforming the national curriculum into the "Merdeka Curriculum," which emphasizes 21st-century learning, in order to foster a superior and competent generation capable of navigating globalization. This aligns with Law No. 20 of 2003 of the Republic of Indonesia, which states that education functions to shape and develop dignified character and civilization while enhancing the nation's intellectual capacity. Similarly, according to the 2016 Ministry of Education and Culture policy, senior high school/vocational school graduates must possess the competencies to think and act creatively, critically, productively, independently, collaboratively, and communicatively (Ismayani, 2016). Therefore, critical and creative thinking skills need to be cultivated and trained continuously.

Creative thinking skills refer to the ability to generate solutions to problems, thereby creating something new or different from existing ideas (Marliani, 2015). Through creative thinking, students are able to perceive the world from multiple perspectives, producing new solutions to real-life problems (Sumarni, 2020). Creative thinking skills play an important role in all forms of learning and are part of higher-order thinking skills that need to be developed. Although creative thinking has received limited attention in product innovation learning, when students engage meaningfully in the learning process, creativity enhances comprehension and fosters cognitive development.

One approach to support such learning is the Project-Based Learning (PjBL) model. PjBL has proven effective in enhancing students' creativity. This model emphasizes not only the final product but also the learning process, where students solve problems and create outcomes. Students are given opportunities to engage in real-life projects, encouraging them to explore creative solutions. Through PjBL, they learn to collaborate, develop communication skills, think critically, and solve problems effectively. Furthermore, this approach nurtures proactive attitudes, responsibility, and time management skills, all of which are crucial for future success.

It is important to provide students with the freedom to gain experiences and understanding through observation and discovery-based learning activities. They also need the opportunity to use various technological and informational tools and media to enrich their learning experiences, as this contributes to fostering creativity inside and outside the classroom. Consequently, in the current curriculum, students are expected to be more active in the learning process, while teachers are encouraged to introduce innovations through various teaching models.

One of the learning models considered effective in enhancing creativity is Project-Based Learning (PjBL). PjBL is a cognitive activity that promotes higher-order thinking skills. It has the advantage of improving learning habits and motivating students to think originally in solving real-life problems (Rahayu *et al.*, 2017). The implementation of PjBL can be integrated with the Science, Technology, Engineering, and Mathematics (STEM) approach (Fitriyani *et al.*, 2020). STEM serves as a preventive approach designed to help students integrate multiple aspects of STEM, emphasizing problem-solving for real-life issues. Each STEM component, when integrated, provides students with a more comprehensive means of addressing problems (Heryuriani & Musdayati, 2020). STEM demonstrates how concepts, principles, and techniques of science, technology, engineering, and mathematics are applied in an integrated manner to develop products, processes, and systems beneficial to human life (XX). Furthermore, STEM has evolved into a multidisciplinary approach with the addition of the Arts, forming STEAM (Mu'minah & Suryaningsih, 2020).

Through the Project-Based Learning model integrated with STEM, this study guides students to explore nature, thereby stimulating spontaneous interest. It allows them to creatively apply knowledge and skills from mathematics, natural sciences, and other disciplines to engage in scientific and technological activities that address simple real-life problems. This integration also provides students with opportunities to validate their theoretical knowledge and achieve harmony between learning and practice.

The PjBL-STEM model is a learning approach that uses projects as the core activity, integrated with STEM (Ismayani, 2016). The model was developed by Diana Laboy Rush, who emphasized that students learn best when they are encouraged to construct their own knowledge about the world around them. Through project-based learning, students are trained to be creative in selecting, designing, and manipulating tools and materials into products that relate to concepts or topics (Afriana & Fitriani, 2016).

Based on observations and interviews with teachers of the Fusion Food subject in Grade XII Culinary Arts at SMK Negeri 1 Bawen, it was found that students' learning outcomes in this subject remained low, indicating the need for instructional methods that can improve learning achievement. Students' critical and creative thinking skills were also found to be low, largely because they tended to remain passive during lessons. The learning process of Fusion Food in Grade XII at SMK Negeri 1 Bawen also showed limited utilization of learning media, both technological and informational, highlighting the need for teaching methods that

maximize such tools. Students have experienced difficulties in understanding the Fusion Food material, further emphasizing the necessity of methods that enable faster and more effective comprehension of Product Innovation topics. Moreover, the teaching of Fusion Food has rarely been conducted in a direct and contextual manner, such as through project-based activities.

2. METHODS

This study is quasi-experimental research using a quantitative method. The research design employed a nonequivalent control group design. The study was conducted at SMK Negeri 1 Bawen with Grade XII Culinary Arts students as the subjects. SMK Negeri 1 Bawen is located at Jl. Kartini Bawen No.119, Mustika, Bawen, Semarang Regency, Central Java, 50661. The research is scheduled to take place from February to April 2025, in accordance with the timetable of the Grade XII Culinary Arts classes at SMK Negeri 1 Bawen. The population of this study consisted of 108 students from Grade XII Culinary Arts at SMK Negeri 1 Bawen in the 2024/2025 academic year. The sampling technique used was proportionate random sampling, resulting in a sample of 72 students. Data were collected through tests, observations, and questionnaires that had been tested for validity and reliability. The data analysis technique employed was MANOVA at a 5% significance level, with testing conducted using SPSS version 26.0.

3. RESULTS AND DISCUSSION

Based on the results of the data analysis using two-way MANOVA, the hypothesis testing yielded in **Table 1**. The results of the two-way MANOVA on the critical thinking skills variable showed an F-value of 51.124 with a significance value of $p = 0.000 < 0.05$. Therefore, the null hypothesis (H_o) was rejected, indicating that the STEM-based Project-Based Learning (PjBL) model had a significant effect on students' critical thinking skills in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen. Accordingly, the first hypothesis stating that "There is an effect of the STEM-based Project-Based Learning (PjBL) model on students' critical thinking skills in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen" was accepted.

Furthermore, the coefficient of determination (R^2) test for the critical thinking variable yielded an R^2 value of 0.414. This indicates that the STEM-based PjBL model contributed 41.4% to the variance in students' critical thinking skills, while the remaining 58.6% was influenced by other factors not examined in this study.

Table 1. Results of two-way MANOVA test for the first hypothesis.

Variable	F-value	p-value	R²
Critical Thinking Skills	51.124	0.000	0.414

The results of the two-way MANOVA on the creativity variable showed an F-value of 80.716 with a significance value of $p = 0.000 < 0.05$ in **Table 2**. Therefore, the null hypothesis (H_o) was rejected, indicating that the STEM-based Project-Based Learning (PjBL) model had a significant effect on students' creativity in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen. Accordingly, the hypothesis stating that "There is an effect of the STEM-based Project-Based Learning (PjBL) model on students' creativity in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen" was accepted.

The coefficient of determination (R^2) test on the creativity variable showed an R^2 value of 0.529. This indicates that students' creativity was influenced by the STEM-based Project-

Based Learning (PjBL) model by 52.9%, while the remaining 47.1% was affected by other factors not included in this study.

Table 2. Results of two-way MANOVA test for the second hypothesis.

Variable	F-value	p-value	R^2
Creativity	80.716	0.000	0.529

The results of the independent samples test showed a significance value of 0.000 < 0.05; therefore, the null hypothesis (H_o) was rejected. Thus, the hypothesis stating that "There is a difference in critical thinking skills between students taught using the STEM-based Project-Based Learning (PjBL) model and those taught using the conventional PjBL model in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen" was accepted. Based on the findings, the average post-test score of students' critical thinking skills in the STEM-based PjBL model was 81.8944, while the average post-test score in the conventional learning model was 72.1028 in **Table 3**. This comparison indicates that students' critical thinking skills under the STEM-based PjBL model were higher than those of students taught using the conventional model.

Table 3. Results of independent samples test for the third hypothesis.

Variable	Learning Model	Mean	t-value	p-value
Critical Thinking Skills	STEM-based PjBL	81.8944	7.150	0.000
	Conventional Model	72.1028		

The results of the independent samples test showed a significance value of 0.000 < 0.05; therefore, the null hypothesis (H_o) was rejected. Thus, the hypothesis stating that "There is a difference in creativity between students taught using the STEM-based Project-Based Learning (PjBL) model and those taught using the conventional learning model in the Fusion Food topic for Grade XII Culinary Arts students at SMK Negeri 1 Bawen" was accepted.

Based on the findings, the average post-test score of students' creativity in the STEM-based PjBL model was 80.9111, while the average post-test score in the conventional learning model was 72.4333. This comparison indicates that students' creativity under the STEM-based PjBL model was higher than that of students taught using the conventional model.

Table 4. Results of independent samples test for the fourth hypothesis

Variable	Learning Model	Mean	t-value	p-value
Creativity	STEM-based PjBL	80.9111	8.984	0.000
	Conventional Model	72.4333		

3.1. The Effect of STEM-Based PjBL Model on Critical Thinking Skills in Fusion Food Topic of Grade XII Culinary Arts at SMK N 1 Bawen"

Based on the analysis, it was found that there is a significant difference in creativity between students taught using the STEM-based Project-Based Learning (PjBL) model and those taught using conventional learning methods. This difference indicates that the STEM-based PjBL model has a significant effect on students' creativity in the Fusion Food topic of Grade XII Culinary Arts at SMK N 1 Bawen. The two-way MANOVA analysis on the creativity variable yielded an F-value of 80.716 with a significance of p = 0.000 < 0.05, confirming the effect of the STEM-based PjBL model on students' creativity. The R^2 test further revealed that

52.9% of the variance in creativity was influenced by the STEM-based PjBL model, while the remaining 47.1% was attributed to other factors not covered in this study.

The independent samples test also supported these findings, showing a significance value of 0.000 < 0.05, which confirmed the differences in creativity between the two groups. The post-test mean score for students taught using the STEM-based PjBL model was 80.91, compared to 72.43 for those taught using conventional learning. These results clearly demonstrate that students taught with the STEM-based PjBL model achieved higher creativity levels. The STEM-based PjBL model encourages students to explore nature, stimulate their intrinsic motivation, and creatively apply their knowledge and skills in mathematics, science, and other disciplines to solve real-world problems. This process provides opportunities for students to verify theoretical knowledge while integrating it into practical applications. As a pedagogical approach, the STEM-based PjBL model integrates project activities with science, technology, engineering, and mathematics (Ismayani, 2016). This model was developed from the perspective that students learn best when they actively construct their own understanding of the world around them (Diana Laboy Rush). Through project-based learning, students are trained to be creative in selecting, designing, and manipulating tools and materials to produce outcomes aligned with the targeted concepts or topics (Afriana & Fitriani, 2016). Therefore, STEM-based PjBL not only enhances students' creativity but also strengthens critical thinking, scientific literacy, and learning outcomes in science and technology fields (Becker & Park, 2011). These findings are consistent with previous studies reporting the positive effects of STEM- and STEAM-based PjBL on students' creative and critical thinking skills (Sukmawijaya *et al*., 2018; Siskawati *et al*., 2020; Fitriyah & Ramadani, 2021; Sumarni & Kadarwati, 2020).

3.2. Students' Responses to the Implementation of PJBL and STEM-Based PJBL on Students' Creativity in Fusion Food Processing Subject

The descriptive analysis showed that students' responses to the STEM-based Project-Based Learning (PJBL) model were categorized as very interesting with a percentage of 72.2%. This indicates that most students felt more enthusiastic and actively engaged when learning through the STEM-based PJBL model compared to conventional PJBL. Students stated that this model provided a more meaningful and interactive learning experience, encouraging them to think creatively and innovatively in producing Fusion Food products. This finding is in line with Ismayani (2016), who explained that STEM-based PJBL creates more meaningful learning experiences since students are encouraged to explore and actively participate in every stage of the project. STEM-based PJBL allows students to build contextual knowledge through the products they create, making the concepts easier to understand and strongly embedded in real-life experiences. Furthermore, STEM-based PJBL requires students to think critically in solving problems, collaborate with peers, and innovate in designing and improving products. Thus, students not only gain conceptual understanding but also develop 21st-century skills such as communication, collaboration, critical thinking, and creativity.

This research also reinforces the findings of Ridha *et al*. (2022), who reported that the STEM-based PJBL learning tools were assessed as very good by teachers and considered effective for use in the classroom. Meanwhile, students' responses to these tools fell into the "good" category, showing that students experienced enhanced learning through active engagement in project activities. In conclusion, the implementation of the STEM-based PJBL model received positive responses from students because it successfully created an engaging, meaningful, and real-life–connected learning process. Moreover, it contributed significantly

to enhancing students' creativity in the Fusion Food Processing subject for grade XII culinary students at SMK N 1 Bawen.

4. CONCLUSION

The implementation of STEM-based PJBL in the Fusion Food subject for grade XII culinary students at SMK N 1 Bawen was proven effective. The model significantly improved students' critical thinking skills (M = 81.89) and creativity (M = 80.91) compared to the conventional PJBL model. Statistical analysis showed that STEM-based PJBL contributed 41.4% to critical thinking and 52.9% to creativity, with the remaining variance influenced by other factors. Furthermore, students' responses were highly positive, with 72.2% rating the model as very interesting.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

6. REFERENCES

Afriana, J., Permanasari, A., and Fitriani, A. (2016). Penerapan project-based learning terintegrasi STEM untuk meningkatkan literasi sains siswa ditinjau dari gender. *Jurnal inovasi pendidikan IPA*, *2*(2), 202-212.

Dewi, N.N.S.K., Arnyana, I.B.P., and Margunayasa, I. G. (2023). Project based learning berbasis STEM: Meningkatkan kemampuan berpikir kritis dan hasil belajar siswa. *Jurnal Ilmiah Pendidikan Profesi Guru*, *6*(1), 133-143.

Fitriyah, A., and Ramadani, S.D. (2021). Pengaruh pembelajaran STEAM berbasis PjBL (project-based learning) terhadap keterampilan berpikir kreatif dan berpikir kritis. *Inspiratif Pendidikan*, *10*(1), 209-226.

Fitriyani, A., Toto, T., and Erlin, E. (2020). Implementasi model PJBL berbasis STEM untuk meningkatkan keterampilan berpikir tingkat tinggi. *Bioed: Jurnal Pendidikan Biologi*, 8(2), 1-6.

Heryuriani, B and Musdayati. (2020). Pembelajaran materi aritmetika sosial dengan pendekatan STEM. *Inomatika*, *2*(2), 55–68.

Ismayani, A. (2016). Pengaruh penerapan STEM project-based learning terhadap kreativitas matematis siswa SMK. *Indonesian Digital Journal of Mathematics and Education, 3*(4), 264–272.

Marliani, N. 2015. Peningkatan Kemampuan Berpikir Kreatif Matematis Siswa Melalui Model Pembelajaran Missouri Mathematics Project (MMP). *Jurnal Formatif*, *1(5),* 14-25.

Mu'minah, I.H., Suryaningsih, Y., Gaffar, A.A., and Sugandi, M.K. (2021). Sosialisasi penggunaan learning management system (LMS) dalam pembelajaran daring untuk guru pada masa pandemi covid-19 di MTsN 2 Majalengka. *Indonesian Journal of Community Service*, *1*(4), 717-729.

Natassya, H. D., Utami, R. E., and Kusumaningsih, W. (2023). Analisis Kemampuan Berpikir kritis siswa dalam menyelesaikan soal tipe *open ended* ditinjau dari mitivasi belajar pada materi SPLTV. *Jurnal Kualita Pendidikan*, *4*(1), 47–53.

Redhana, W. (2019). Mengembangkan keterampilan abad ke-21 dalam pembelajaran kimia. *Jurnal Inovasi Pendidikan Kimia*, *13*(1), 2239–2253.

Ridha, M. R., Zuhdi, M., and Ayub, S. (2022). Pengembangan perangkat pembelajaran PjBL berbasis STEM dalam meningkatkan kreativitas fisika peserta didik. *Jurnal Ilmiah Profesi Pendidikan*, *7*(1), 223-228.

Siskawati, G. H., Mustaji, M., and Bachri, B. S. (2020). Pengaruh project-based learning terhadap kemampuan berfikir kreatif siswa pada pembelajaran online. *Educate: Jurnal Teknologi Pendidikan*, *5*(2), 31-42.

Sukmawijaya, Y., Suhendar, S., and Juhanda, A. (2019). Pengaruh model pembelajaran stem-pjbl terhadap kemampuan berpikir kreatif siswa pada materi pencemaran lingkungan. *Jurnal BIOEDUIN*, *9*(2), 28-43.

Sumarni, W. (2020). Analisis kemampuan berpikir kritis setelah penerapan problem-based learning berbantuan lembar kerja peserta didik bermuatan etnosains. *Phenomenon: Jurnal Pendidikan MIPA*, *9*(2), 206-218.

Sumarni, W., and Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11- 21.

Yusmar, F., and Fadilah, R. E. (2023). Analisis rendahnya literasi sains peserta didik indonesia: Hasil PISA dan faktor penyebab. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *13*(1), 11-19.