
Implementing Project-Based Learning through Metal Product Fabrication in Vocational Automotive Education

Busyairi Majid¹, Ari Dwi Nur Indriawan Musyono²

¹² Mechanical Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Semarang, Indonesia

Article Info

Article history:

Received July 21, 2026

Revised July 28, 2026

Accepted July 31, 2026

Published Oct 30, 2026

Keywords:

Automotive vocational education

Metal fabrication

Occupational safety

Practical skills

Project-based learning

ABSTRACT

This study describes the implementation of Project-Based Learning (PjBL) through metal-product fabrication in the Creative Products and Entrepreneurship (CP&E) subject for Grade XI students in the Light Vehicle Engineering program. A descriptive case study was conducted with 20 students at SMK Mataram Semarang from February to May 2026 over 12 meetings. The students were organized into three groups that fabricated two long metal benches and one shoe rack. Data were obtained from a student-response questionnaire, a process-and-product assessment rubric, a 12-item teacher-response instrument, documentation, and implementation notes. The analysis of student responses focused on nine indicators of PjBL implementation. The response indicators ranged from 78% to 83%, indicating positive to very positive responses. Group 1 obtained 38 points and was categorized as very good, whereas Groups 2 and 3 obtained 34 and 33 points and were categorized as good. The teacher-response instrument yielded 43 of 48 points (89.58%) and was categorized as very good, although incomplete finishing received the lowest rating. The main constraints were limited practice time and materials, uneven participation among groups, and incomplete paintings in two groups. The findings indicate that PjBL involving metal-product fabrication can provide an authentic vocational learning experience when materials, time allocation, task distribution, safety supervision, and assessment rubrics are systematically prepared. Practically, these findings provide vocational teachers with a planning framework for selecting feasible products, organizing group roles, scheduling staged inspections, and reserving sufficient time for finishing in CP&E instruction.

Corresponding Author:

Busyairi Majid

Mechanical Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Semarang, Indonesia

Email: majid22@students.unnes.ac.id

INTRODUCTION

Vocational education is intended to prepare learners to connect disciplinary knowledge with occupational skills, professional attitudes, and workplace expectations. In vocational high schools, instruction should extend beyond theoretical explanation by giving students opportunities to operate tools, follow work procedures, apply occupational health and safety principles, communicate

effectively, collaborate, and produce tangible work that can be evaluated. Both technical and non-technical capabilities are essential to vocational students' readiness for employment (Widodo et al., 2025). Educators' competencies must also be strengthened so that instruction remains aligned with industrial developments (Amitiurna et al., 2025), while the relevance of learning increases when school assignments are explicitly connected to workplace activities and competencies (Hiim, 2023).

The Creative Products and Entrepreneurship (CP&E) subject in the Light Vehicle Engineering program provides an appropriate setting in which practical competence, creativity, responsibility, and product orientation can be integrated. Fabricating metal workpieces enables students to engage in an authentic sequence of activities, including interpreting sketches, estimating material requirements, measuring, cutting, assembling, welding, finishing, and evaluating the completed product. Visual representations and technical guidance can help students understand product forms, dimensions, and production procedures (Azizah & Herwanto, 2024). Such activities may also strengthen students' understanding of product utility and entrepreneurship (Hendi et al., 2025). In metalwork, procedural precision and joint quality directly affect the quality of the final product (Wibowo et al., 2025). Nevertheless, school-based production practice is often constrained by the availability of materials, time, equipment, and effective group-task distribution. Consequently, both the production process and the resulting product need to be planned and assessed in a balanced manner.

Project-Based Learning is particularly relevant to this setting because it places projects and products at the center of the learning experience. A comprehensive PjBL process includes a meaningful goal or problem, systematic planning, collaborative work, decision-making, artifact production, process monitoring, and evaluation of results (Markula & Aksela, 2022). It also emphasizes learning through product development, authentic problem-solving, collaboration, and iterative revision (Shin et al., 2021). Product-oriented studies have shown that a tangible product can connect creativity, project management, and student innovation (Zhan et al., 2022). Similarly, project-based STEM learning demonstrates considerable educational value while also revealing challenges associated with tool use and practical implementation (Chang & Chen, 2022). In welding technology, a structured application of PjBL has been reported to support vocational students' cognitive, affective, and psychomotor competencies (Rahim et al., 2024).

A substantial proportion of research on PjBL in vocational education has employed experimental designs to compare learning outcomes. A meta-analysis indicates that PjBL can contribute to academic achievement, attitudes, and thinking skills, although the magnitude of its effects depends on implementation characteristics and research context (Zhang & Ma, 2023). Experimental designs are useful for testing effects, but they do not always explain how projects unfold under actual classroom and workshop conditions. Such conditions may include changes in the intended product because of material shortages, unequal participation, unfinished product finishing, and the need for sustained safety supervision. The development of PjBL syntax for vocational education likewise underscores the

importance of clearly structured project stages from initial planning to the presentation of outcomes (Akhyar et al., 2024). Furthermore, PjBL outcomes should be interpreted by considering the learning environment, process, skills, and evidence embodied in the product rather than relying on a single measure (Cruz et al., 2022). Accordingly, this study treats student responses as descriptive data and triangulates them with process-and-product rubrics, teacher responses, documentation, and implementation notes.

The contribution of this study lies in its detailed account of PjBL implementation through metal product fabrication in the CP&E subject under authentic instructional conditions. This study extends prior implementation-oriented research by integrating student responses across nine indicators with group-level process-and-product scores, teacher responses, expert-reviewed instruments, documentation, and records of material, participation, and finishing constraints. This combination makes it possible to trace how resource limitations and group-work conditions shaped both the learning process and the completed products. Rather than attempting to establish a causal improvement in learning outcomes, the study describes the project process, student responses, the quality of the process and products, instrument validation, teacher responses, and the constraints encountered during implementation. Therefore, the study aims to describe the implementation of metal-product-based PjBL, students' responses, the quality of project processes and outputs, and the factors that require improvement in practical CP&E instruction.

METHOD

This study employed a descriptive approach in the form of an instructional implementation case study. This approach was selected because the study did not involve a control class, pretest-posttest measurements, or inferential statistical testing. Quantitative data were used to summarize student responses, process-and-product assessments, and teacher responses, while qualitative data were obtained from documentation, teacher comments, and records of implementation constraints. The findings should therefore be interpreted as an account of PjBL implementation in a single instructional context rather than as evidence of a causal effect.

The study was conducted at SMK Mataram Semarang in the Light Vehicle Engineering program. The project-based instruction was implemented in the Creative Products and Entrepreneurship subject over 12 meetings between February and May 2026. The participants were 20 Grade XI Light Vehicle Engineering students. They were divided into three working groups. Groups 1 and 2 each consisted of seven students and produced a long metal bench, whereas Group 3 consisted of six students and produced a shoe rack after the original plan was modified because of limited practice materials. The study was conducted after permission had been obtained from the school administration and the subject teacher. Student identities were excluded from data processing and reporting, and all documentation was used exclusively for research purposes.

Table 1. Group composition and project products

Group	Number of students	Product
Group 1	7 students	Long metal bench
Group 2	7 students	Long metal bench
Group 3	6 students	Shoe rack

The PjBL process began with an explanation of the project objectives, the products to be developed, work procedures, required tools and materials, occupational health and safety requirements, and assessment criteria. Students subsequently interpreted working drawings or sketches, distributed responsibilities, measured and cut materials, assembled components, welded joints, completed finishing work, evaluated the products, and received teacher feedback. The teacher supervised tool use and high-risk procedures while allowing students to remain responsible for organizing group activities and adapting their work when constraints emerged. Structured project stages help maintain coherence between planning, implementation, and presentation of outcomes (Akhyar et al., 2024), while visual media and technical instructions can clarify the product form and production procedures that students are expected to follow (Azizah & Herwanto, 2024).

Table 2. Summary of instruments and data-collection techniques

Instrument and data source	Structure	Primary analytical use
Student response questionnaire (20 Grade XI Light Vehicle Engineering students)	Five-point Likert scale. Part A contained 15 statements concerning PjBL implementation; Part B contained 10 statements concerning learning outcomes and skills.	The primary analysis focused on Items 2, 3, 4, 5, 6, 10, 13, 14, and 15, representing nine PjBL indicators. Part B was not treated as a principal outcome because it consisted of students' self-assessments.
Process-and-product rubric (three project groups)	Four-point scale. Maximum scores were 20 for the product, 20 for the process, and 40 in total.	Assessed planning, collaboration, practical skills, tool use and safety, time management, product conformity, construction quality, dimensional accuracy, finishing, and product completion.
Teacher response instrument (CP&E subject teacher)	Twelve statements scored on a four-point scale, each accompanied by an open-ended comment field.	Assessed project objectives and stages, participation, collaboration, tool use and safety, completion, adaptation, product function and construction, finishing, practical skills, responsibility, and feasibility for future implementation.
Documentation and implementation notes (teacher and activity records)	Photographs of processes and products, group lists, teacher notes, and records of constraints.	Provided supporting qualitative evidence concerning the project process, limitations of materials and time, group participation, and product completion.

For the process-and-product rubric, total scores of 36-40 were categorized as very good, scores of 30-35 as good, scores of 20-29 as satisfactory, and scores below 20 as requiring improvement. Occupational health and safety was retained as a distinct assessment aspect because the use of workshop tools and materials requires appropriate safety knowledge, attitudes, and supervision (Dewangga et al., 2025).

During the preparation of the final analysis, the instruments and reporting focus were reviewed by one university-based expert in educational evaluation with experience in assessing learning instruments for vocational and practical instruction. The review addressed alignment between instrument content and the study objectives, clarity of indicators, linguistic precision, readability, appropriateness of the rating scales, and feasibility for vocational practical instruction. Based on the review, the student-response analysis was narrowed to nine indicators that directly represented PjBL implementation, while self-reported learning-outcome items were excluded from the primary analysis. The wording of several teacher-response statements was simplified to reduce ambiguity, and the process-and-product rubric was checked for alignment with the sequence and characteristics of metal-product fabrication. Based on the available review notes, the student response questionnaire was considered suitable after revision, while the process-and-product rubric and teacher response instrument were considered appropriate for use. Because the review document did not include quantitative scores, the validation results are reported qualitatively in terms of feasibility decisions and the subsequent revisions made.

The data were analyzed descriptively. Student responses to the nine selected items were summed for each indicator and compared with the maximum possible score of 100, calculated as 20 students multiplied by a maximum score of 5. Mean scores and percentages were then calculated. For descriptive presentation, the percentages were classified into five equal-width intervals: 0%-20% as very low, more than 20%-40% as low, more than 40%-60% as moderate, more than 60%-80% as positive, and more than 80%-100% as very positive. Calculations were based on individual item responses. All manually recorded questionnaire totals were rechecked by recalculating the item scores. When discrepancies were found, the analysis used the recalculated item-level scores. The process-and-product rubric was analyzed using product subtotals, process subtotals, total scores, categories, and teacher notes. Teacher responses were calculated across 12 items against a maximum score of 48 and interpreted together with the comments attached to each item. The analysis was not used to claim statistically significant improvement or causal relationships because the study did not employ pretest-posttest measurements or a comparison group.

RESULTS AND DISCUSSION

Implementation of Project-Based Learning in Creative Products and Entrepreneurship Instruction

PjBL was implemented over 12 meetings between February and May 2026 through projects involving the fabrication of metal workpieces. At the beginning of the activity, the teacher explained the

objectives, products, tools and materials, work procedures, occupational health and safety requirements, and assessment rubric. Students then worked in three groups. Two groups produced long metal benches, while one group produced a shoe rack after the original plan was adjusted to accommodate material shortages. This modification demonstrates that the project did not take place under ideal conditions; instead, both students and the teacher had to make decisions based on the resources that were actually available.

The practical stages consisted of planning, task distribution, measurement, cutting, assembly, welding, finishing, and product evaluation. These activities combined technical and non-technical competencies. Technical competence was reflected in tool operation and material processing, whereas non-technical competence was evident in communication, collaboration, responsibility, time management, and problem-solving. This pattern is consistent with PjBL, which integrates inquiry, collaboration, decision-making, and the creation of a tangible product within a single learning sequence (Markula & Aksela, 2022). Project work can also strengthen student engagement and character development in vocational education (Putra et al., 2025) and support interpersonal competence when roles, activities, and reflection are clearly designed (Crespí et al., 2022; Widodo et al., 2025).

The products provided a more authentic work context than isolated exercises without a defined practical purpose. Students were required to consider the relationships among dimensional accuracy, joint quality, neatness, time allocation, and product functionality. Connecting instructional content with authentic vocational tasks is central to maintaining the relevance of vocational education (Hiim, 2023). Integrating project-based instruction with production settings may also strengthen the relationship between educational activities and practical workplace demands (Wang et al., 2023). The present findings are broadly consistent with Rahim et al. (2024), although that study employed an experimental design, whereas the present study is limited to a descriptive account of implementation in one class.

Assessment of the Project Process and Products

The teacher's assessment indicated that all groups achieved either good or very good performance. The results are presented in terms of product subtotal, process subtotal, total score, category, and teacher comments. Scores for individual aspects could not be analyzed separately because the available summary sheet contained only subtotal scores.

Table 3. Group-level process-and-product assessment results

Group	Product	Product score	Process score	Total	Category	Teacher's notes
Group 1	Long metal bench	19/20	19/20	38	Very good	The product was completed; collaboration and product quality were good.
Group 2	Long metal bench	18/20	16/20	34	Good	The main construction was completed, but painting was unfinished.

Group	Product	Product score	Process score	Total	Category	Teacher's notes
Group 3	Shoe rack	18/20	15/20	33	Good	The product was changed because of material limitations; the final form was completed, but it was not painted.

Note: The maximum score for each product and process subtotal was 20.

Group 1 obtained a product score of 19 and a process score of 19, resulting in a total score of 38 and a very good classification. Group 2 obtained a product score of 18 and a process score of 16, for a total of 34. Although the main construction of the long metal bench was completed, the painting stage could not be finished. Group 3 obtained a product score of 18 and a process score of 15, for a total of 33. This group successfully adapted the project by producing a shoe rack because of material constraints and completed its final structural form, although painting was not undertaken.

Groups 2 and 3 received lower process scores than product scores. This difference indicates that the principal structural quality of the products remained good, but the implementation process was not fully optimal because of limited time, unequal participation, weaknesses in group-work management, material adjustments, and unfinished final work. The discrepancy reinforces the need to assess both process and product in practical instruction. In project-based learning, the product should be evaluated together with students' ability to manage the process, exercise creativity, and solve problems (Zhan et al., 2022). Meta-analytic evidence likewise suggests that PjBL findings must be interpreted in relation to the type of outcome measured and the characteristics of implementation (Zhang & Ma, 2023).

Expert Validation of the Instruments

Before the final analysis was conducted, all three instruments were reviewed by one expert validator. Because the source validation forms did not contain quantitative scores, the results are reported as feasibility decisions and follow-up revisions. Table 4 summarizes the validation results.

Table 4. Summary of validation by one expert reviewer

Instrument	Validation result	Revision or follow-up action
Student response questionnaire	Suitable with revision	The analysis was limited to nine PjBL indicators; self-reported learning-outcome indicators were excluded from the main analysis.
Process-and-product rubric	Suitable for use	The rubric was aligned with metal products and the scoring sequence in the original instrument.
Teacher response instrument	Suitable for use	The wording of the statements was simplified.

The validation process indicated that the student response questionnaire required refinement in the focus of analysis, whereas the process-and-product rubric and the teacher response instrument were appropriate for use. Student perceptions can provide evidence of acceptance and engagement, but they cannot replace tests, performance assessments, or product artifacts when demonstrating improvement in learning outcomes. For this reason, Part B of the questionnaire was not analyzed as a primary outcome.

Student Responses to Project-Based Instruction

Student responses were calculated from nine selected items across 20 completed questionnaires. The maximum score for each indicator was 100, and the maximum mean score was 5. Table 5 presents the mean score, percentage, and descriptive category for each indicator.

Table 5. Student responses across nine indicators

Student response indicator	Mean score	Percentage	Category
Understanding of the project	4.00	80%	Positive
Active participation in practice	4.10	82%	Very positive
Group collaboration	4.15	83%	Very positive
Teacher guidance	4.15	83%	Very positive
Practical skills	4.05	81%	Very positive
Responsibility	4.10	82%	Very positive
Problem-solving	3.90	78%	Positive
Occupational safety	4.15	83%	Very positive
Authentic work experience	3.90	78%	Positive

Note: Categories were derived from five equal-width descriptive intervals; percentages greater than 80% up to 100% were classified as very positive, and percentages greater than 60% up to 80% were classified as positive.

The highest percentages were recorded for group collaboration, teacher guidance, and occupational safety. Each of these indicators achieved a mean score of 4.15 or 83% and was classified as very positive. Active participation and responsibility each obtained a mean score of 4.10 or 82%, while practical skills achieved 4.05 or 81%; all three were also classified as very positive. Understanding of the project obtained a mean score of 4.00 or 80% and was classified as positive. The two lowest indicators were problem-solving and authentic work experience, each with a mean score of 3.90 or 78%, although both remained within the positive category. The relatively lower problem-solving score may reflect students' continued dependence on teacher guidance when materials were limited, work plans changed, or technical difficulties occurred. The authentic-work-experience score may have been affected by the school-based setting, limited materials and time, unequal participation, and the absence of complete industrial production conditions, particularly at the finishing stage. This pattern indicates broad acceptance of the learning process while suggesting that students' independence in addressing project problems and connecting the activity to real workplace situations still requires further development.

Conceptually, project experience may foster communication, collaboration, responsibility, and problem-solving. Crespi et al. (2022) reported that PjBL can develop interpersonal competencies when activities, roles, and reflective processes are designed clearly. Chang and Chen (2022) similarly demonstrated that project-based learning provides valuable direct experience while still presenting challenges in tool use and task completion. In the present study, however, participation was not entirely

balanced across group members. Therefore, positive responses should not be interpreted as evidence that every student had an equivalent experience or that learning outcomes increased significantly.

Teacher Responses to the Implementation

The teacher response instrument yielded a score of 43 out of a maximum of 48, equivalent to 89.58%, and was classified as very good in the source instrument. Eight aspects received a score of 4: understanding of objectives and stages, student participation, collaboration, adaptation to constraints, product functionality, practical skills, responsibility, and feasibility for future use. Tool use and safety, completion according to plan, and construction quality received scores of 3. Product finishing received the lowest score of 2 because several groups did not complete the painting stage. Future implementation should improve this stage by preparing paint and surface-treatment materials before the project begins, setting a finishing deadline before the final meeting, conducting staged checks of grinding and surface preparation, assigning specific finishing roles within each group, and reserving at least one dedicated session for painting, drying, inspection, and minor correction.

Table 6. Teacher responses to product-based instruction

No.	Assessed aspect	Score	Teacher's principal comment
1	Understanding of objectives and stages	4	Most students understood the sequence of work.
2	Student participation	4	Each group was actively involved in practical work.
3	Group collaboration	4	Tasks were distributed reasonably well, and members supported one another.
4	Tool use and occupational safety	3	Procedures were generally followed, although continued supervision was necessary.
5	Completion according to plan	3	Some groups did not complete the painting stage.
6	Adaptation to constraints	4	Group 3 adapted by changing the intended product.
7	Product functionality	4	The products functioned in accordance with their intended purposes.
8	Construction quality	3	The construction was good, but the final stage required improvement.
9	Product finishing	2	Several groups did not complete the painting stage.
10	Practical skills	4	The teacher observed improvement in measurement, welding, and assembly skills.
11	Student responsibility	4	Students demonstrated stronger responsibility for the group product.
12	Feasibility for future implementation	4	The method was considered appropriate for practical learning experiences.

Total score = 43 out of 48 (89.58%); category in the source instrument = very good.

The teacher's group-specific comments were consistent with the process-and-product rubric. Group 1 completed the long metal bench according to the original plan and completed all production stages. Group 2 completed the main bench construction, but the painting stage remained unfinished. Group 3 revised its plan because of limited materials, changed the product to a shoe rack, and completed the final

structural form without painting. Thus, the most consistent constraints across the rubric and teacher response data concerned material readiness and the time available for finishing.

The teacher's role in PjBL is not to complete the project on behalf of students, but to provide direction, monitor safety, pose questions, and offer timely feedback. Such support should be accompanied by a traceable division of responsibilities so that a small number of highly active students do not dominate the entire project. Continuing professional development and stronger connections with industrial practice are important for improving teachers' ability to manage contextualized vocational instruction (Amitiurna et al., 2025). In future implementation, a role-distribution sheet and individual progress records could be used to strengthen group accountability.

Constraints in PjBL Implementation

The principal constraints were limited time, insufficient materials, incomplete finishing, and unequal participation among group members. Material shortages caused Group 3 to change the intended product. Time limitations prevented two groups from completing the painting stage. These findings indicate that product complexity must be aligned with the number and duration of instructional meetings, students' initial abilities, and the availability of materials.

These constraints should not be omitted from the report because they constitute part of the findings of an implementation study. On the contrary, they explain why product scores varied across groups and why the quality of learning should not be judged solely from the final physical form. Evaluation of vocational practice programs needs to account for implementation processes and actual field conditions rather than focusing only on the final result (Yulianti et al., 2024). Future implementation should therefore include a detailed material list, reserve materials, stage-specific deadlines, explicit role allocation, advance distribution of the rubric, and dedicated time for finishing and evaluation.

Occupational health and safety must remain non-negotiable even when time is limited. Teacher supervision, equipment inspection, use of personal protective equipment, and the immediate suspension of unsafe work must take precedence over the pressure to complete a product. Students' safety knowledge and attitudes are associated with safe behavior during workshop practice (Dewangga et al., 2025). With these safeguards in place, metal projects can serve as authentic yet controlled vocational learning experiences.

Practical Implications for CP&E Instruction

The findings have several implications for the planning of CP&E instruction. First, teachers should define a realistic project scope based on the number of meetings, students' initial competence, available tools, and the volume of materials. Excessively complex products may cause students to prioritize completion over understanding the process, whereas overly simple products may not provide sufficient challenge in planning, problem-solving, and quality evaluation. The selected instructional model should balance the development of knowledge, practical skills, and work attitudes among mechanical

engineering students (Widarto et al., 2024). Product selection should therefore consider functionality, joint complexity, the number of components, finishing requirements, and occupational risks.

Second, the rubric should be distributed before practical work begins and used as a learning guide rather than only as a scoring instrument. Students need to understand that planning, collaboration, tool use, safety, dimensional accuracy, construction quality, finishing, and product completion are assessed through explicit criteria. Advance access to the rubric can help each group establish targets and monitor progress. Teachers may also add a brief control sheet for each meeting that records completed work, encountered constraints, plans for the next meeting, and the members responsible for specific tasks. This procedure may reduce the dominance of certain students while generating stronger process evidence for assessment.

Third, project evaluation should be conducted progressively. Feedback should not be postponed until the product is completed because errors in measurement, assembly sequence, or joint preparation may become difficult to correct at a later stage. Interim checks can be conducted after planning, cutting, initial assembly, welding, and finishing. This approach is consistent with the principle that monitoring and revision are integral components of PjBL rather than supplementary activities undertaken after project completion (Markula & Aksela, 2022; Shin et al., 2021). In vocational settings, staged inspection also enables teachers to connect product-quality standards with safe and systematic work habits.

Study Limitations

This study has several limitations that should be acknowledged. The participants consisted of only 20 students from one class and one school; consequently, the findings cannot be generalized to all students in Light Vehicle Engineering programs. The study also did not include a comparison group or measurements before and after instruction. Therefore, the rubric scores and response data cannot be used to conclude that PjBL caused an improvement in competence. The findings are more appropriately understood as a contextual description of implementation and as a basis for instructional improvement.

Additional limitations concern the instruments and the traceability of the data. The rubric summary did not report scores for each individual aspect, which restricted the analysis to product and process subtotals. Instrument validation involved only one expert reviewer, and the source documents did not provide quantitative validation scores or a complete description of the reviewer's field of expertise. The initial questionnaire was developed based on the long metal bench project. For the group that produced a shoe rack, student responses were interpreted within the broader context of metal product fabrication. To ensure accuracy, questionnaire data were analyzed based on item-level responses rather than relying solely on manually written totals. Future studies should use product-specific instruments consistently, involve more than one validator, provide digital item-level records, and document the validation procedure in greater detail.

CONCLUSION

Project-Based Learning through metal product fabrication was implemented in the CP&E subject for Light Vehicle Engineering students as a descriptive study of practical instruction. Across 12 meetings from February to May 2026, students completed activities involving planning, measurement, cutting, assembly, welding, finishing, and product evaluation. Group 1 achieved a score of 38 and was classified as very good, whereas Groups 2 and 3 received scores of 34 and 33, respectively, and were classified as good. Student responses across nine indicators ranged from 78% to 83%, representing positive to very positive categories. The teacher response score was 43 out of 48, or 89.58%, and was classified as very good in the source instrument, although finishing received the lowest score. For vocational teachers and curriculum implementers, the findings emphasize the need to align project complexity with available meetings and resources, use transparent role and assessment systems, and allocate a dedicated finishing phase within CP&E learning plans.

The findings indicate that the principal value of PjBL lies in connecting the work process with a tangible product, collaboration, responsibility, problem-solving, and occupational safety. Nevertheless, positive student responses and teacher assessments do not constitute causal evidence of improved learning outcomes. Future implementation should ensure earlier preparation of materials, alignment between product complexity and available time, clearer role distribution, stronger monitoring of individual contributions, dedicated time for finishing, and continuous safety supervision throughout all stages of practical work.

ACKNOWLEDGMENT

The authors express their appreciation to the school leadership, the Creative Products and Entrepreneurship teacher, and the staff of SMK Mataram Semarang for granting permission and supporting the data-collection process. The authors also thank the Mechanical Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Semarang, for administrative support and academic guidance during the preparation of this manuscript.

REFERENCES

- Akhyar, M., Ihsan, F., Suharno, S., Tamrin, A. G., & Purwanto, P. (2024). Development of problem and project-based learning syntax to improve vocational student learning outcomes. *Jurnal Pendidikan Teknologi dan Kejuruan*, 30(1), 1-19. <https://doi.org/10.21831/jptk.v30i1.53968>
- Amitiurna, C., Puspitasari, M., Pelawi, M. A., & Prayoga, P. H. N. (2025). Enhancing vocational education through continuous professional development: Analysing the non-degree program for Indonesian polytechnic lecturers. *Jurnal Pendidikan Vokasi*, 15(1), 1-11. <https://doi.org/10.21831/jpv.v15i1.83912>

- Azizah, A. I., & Herwanto, H. W. (2024). Google Sites: Development of 3D CAD tutorial video for class XI at SMKN 1 Blitar. *Jurnal Dinamika Vokasional Teknik Mesin*, 9(1), 68-74. <https://doi.org/10.21831/dinamika.v9i1.73640>
- Chang, C.-C., & Chen, Y.-K. (2022). Educational values and challenges of i-STEM project-based learning: A mixed-methods study with data-transformation design. *Frontiers in Psychology*, 13, 976724. <https://doi.org/10.3389/fpsyg.2022.976724>
- Crespí, P., García-Ramos, J. M., & Queiruga-Dios, M. (2022). Project-based learning (PBL) and its impact on the development of interpersonal competences in higher education. *Journal of New Approaches in Educational Research*, 11, 259-276. <https://doi.org/10.7821/naer.2022.7.993>
- Cruz, S., Viseu, F., & Lencastre, J. A. (2022). Project-based learning methodology as a promoter of learning math concepts: A scoping review. *Frontiers in Education*, 7, 953390. <https://doi.org/10.3389/educ.2022.953390>
- Dewangga, A. W., Djatmiko, R. D., & Majid, A. (2025). The relationship of knowledge and attitude to occupational health and safety behavior in machining workshop. *Jurnal Dinamika Vokasional Teknik Mesin*, 10(1), 37-50. <https://doi.org/10.21831/dinamika.v10i1.83925>
- Hendi, M., WP, A. Y., & Abizar, H. (2025). The influence of entrepreneurial knowledge, self efficacy and entrepreneurial character on entrepreneurial interest of class XII students of SMKN 7 Pandeglang. *Jurnal Dinamika Vokasional Teknik Mesin*, 10(1), 98-110. <https://doi.org/10.21831/dinamika.v10i1.84092>
- Hiim, H. (2023). How can collaboration between schools and workplaces contribute to relevant vocational education? *Vocations and Learning*, 16, 1-21. <https://doi.org/10.1007/s12186-022-09300-z>
- Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: How teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, 4, Article 2. <https://doi.org/10.1186/s43031-021-00042-x>
- Putra, A. Y. W., Sanam, S., Abdillah, H., & Fawaid, M. (2025). An evaluation of Pancasila student profile strengthening project in vocational schools: Evidence from Tangerang district. *Jurnal Pendidikan Vokasi*, 15(1), 45-58. <https://doi.org/10.21831/jpv.v15i1.79919>
- Rahim, B., Ambiyar, A., Waskito, W., Fortuna, A., Prasetya, F., Andriani, C., Andriani, W., Sulaimon, J., Abbasinia, S., Luthfi, A., & Salman, A. (2024). Effectiveness of project-based learning in metal welding technology course with STEAM approach in vocational education. *TEM Journal*, 13(2), 1481-1492. <https://doi.org/10.18421/TEM132-62>
- Shin, N., Bowers, J., Krajcik, J., & Damelin, D. (2021). Promoting computational thinking through project-based learning. *Disciplinary and Interdisciplinary Science Education Research*, 3, Article 7. <https://doi.org/10.1186/s43031-021-00033-y>

- Wang, X., Lee, C.-F., Li, Y., & Zhu, X. (2023). Digital transformation of education: Design of a “project-based teaching” service platform to promote the integration of production and education. *Sustainability*, 15(16), 12658. <https://doi.org/10.3390/su151612658>
- Wibowo, H., Marwanto, A., Putera, R. H. S., & Fakhri, A. A. (2025). Optimizing of groove angle in welding cast aluminum A356 for product repair. *Jurnal Dinamika Vokasional Teknik Mesin*, 10(1), 51-59. <https://doi.org/10.21831/dinamika.v10i1.84120>
- Widarto, W., Jarwopuspito, J., Rahdiyanta, D., Wibowo, A. E., & Djati, U. I. (2024). The comparison of block learning with traditional learning in developing three competency aspects of mechanical engineering students. *Jurnal Dinamika Vokasional Teknik Mesin*, 9(1), 51-68. <https://doi.org/10.21831/dinamika.v9i1.73616>
- Widodo, S. F. A., Munadi, S., Harjanto, C. T., Prasetya, T. A., & Muflih, B. K. (2025). Managing soft skills development in vocational higher education: A case study of institutional practices in Indonesia. *Jurnal Pendidikan Vokasi*, 15(2), 132-141. <https://doi.org/10.21831/jpv.v15i2.73825>
- Yulianti, D., Abizar, H., & Abdillah, H. (2024). Implementation evaluation of the student’s field work practice program in the Vocational School 7 Serang, using the Countenance Stake Model. *Jurnal Dinamika Vokasional Teknik Mesin*, 9(2), 140-159. <https://doi.org/10.21831/dinamika.v9i2.78226>
- Zhan, Z., Shen, W., & Lin, W. (2022). Effect of product-based pedagogy on students’ project management skills, learning achievement, creativity, and innovative thinking in a high-school artificial intelligence course. *Frontiers in Psychology*, 13, 849842. <https://doi.org/10.3389/fpsyg.2022.849842>
- Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: A meta-analysis study. *Frontiers in Psychology*, 14, 1202728. <https://doi.org/10.3389/fpsyg.2023.1202728>