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Problem-Based Learning to Support Creative Thinking Skills in Automotive Engineering Students: A Classroom Action Research Study

Ilham Yuliady[1]*, Zulfadli[1], Erik Fernandes[2],Yogi Dian Alfana[2]

Abstract

Low creative thinking skills in automotive engineering learning can limit students' ability to generate, adapt, and elaborate technical solutions. This study described the implementation of Problem-Based Learning (PBL) and examined changes in students' creative thinking skills in the Fundamentals of Automotive Engineering course. A Classroom Action Research design was used with 21 Automotive Engineering students and conducted in two cycles consisting of planning, action, observation, and reflection. Data were collected using observation sheets on creative thinking indicators and analyzed descriptively based on creativity categories. In the pre-cycle condition, most students were classified as fairly creative (52.38%), while only 4.76% were very creative. After PBL implementation in Cycle II, the creative category increased to 47.62% and the very creative category increased to 28.57%, while the least creative category decreased to 0%. These findings suggest that PBL can support the development of students' creative thinking in automotive engineering learning.

Keywords
Problem-Based Learning; creative thinking skills; Classroom Action Research; automotive engineering education; Fundamentals of Automotive Engineering.

[1] Department of Automotive Engineering, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Air Tawar, Padang Utara, Padang, West Sumatra 25132, Indonesia
[2] Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang
Jl. Prof. Dr. Hamka, Air Tawar, Padang Utara, Padang, West Sumatra 25132, Indonesia

* ilhamyuliady@ft.unp.ac.id

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INTRODUCTION

Automotive engineering education is expected to prepare students to respond to rapid technological change, workplace competency demands, and increasingly complex technical problems in the automotive sector. Recent studies in automotive vocational education have emphasized that graduates need competencies that are aligned with current industry needs, including technical adaptability, problem-solving ability, and readiness to work in technology-oriented automotive environments [1]. At the instructional level, learning innovation in automotive education has also moved toward more interactive, contextual, and practice-oriented approaches, such as smart trainers integrated with QR codes and video-based learning media for vehicle electrical systems [2], [3]. These developments indicate that automotive learning should not only transfer technical knowledge but also provide learning experiences that encourage students to observe, analyze, discuss, and construct solutions to authentic technical problems.

In the Fundamentals of Automotive Engineering course, creative thinking is an important capability because students are required to understand automotive concepts, interpret technical situations, and propose alternative solutions to vehicle-related problems. Creative thinking is commonly reflected through four indicators: fluency, flexibility, originality, and elaboration [4]. In an automotive learning context, fluency refers to the ability to generate several possible ideas or solutions; flexibility refers to the ability to view a problem from different technical perspectives; originality refers to the ability to propose uncommon but relevant ideas; and elaboration refers to the ability to develop ideas into more detailed and technically reasonable explanations. However, the initial condition in this study showed that students' creative thinking skills were still not optimally developed. Before the intervention, most students were classified as fairly creative, while only a small proportion reached the very creative category. This condition indicates that students still needed a learning environment that could stimulate idea generation, alternative solution development, and deeper technical reasoning.

Problem-Based Learning (PBL) is one instructional model that can support the development of creative thinking because it places authentic problems at the center of the learning process. Through PBL, students are encouraged to understand problems, collect information, discuss possible solutions, make decisions, and reflect on the solution process. A meta-analysis of PBL studies reported that PBL has the potential to improve students' creative thinking skills because it actively engages learners in problem solving and knowledge construction [5]. Similar findings have been reported in empirical studies showing that PBL can support students in developing creative ideas, divergent thinking, and problem-solving ability [6], [7]. However, these studies are mostly situated in general education or non-automotive contexts, and many of them focus on final learning outcomes rather than describing how students' creativity develops during the learning process.

Several recent studies have attempted to examine PBL more contextually. Classroom Action Research on PBL has shown that repeated cycles of planning, action, observation, and reflection can be used to monitor the development of problem-solving and creative thinking skills during the learning process [8]. In vocational education, PBL has also been reported to support student creativity because it provides opportunities for learners to solve realistic tasks and express ideas more actively [9]. In automotive vocational education, PBL-based approaches have been developed to improve problem-solving and communication skills through teaching factory learning, and other studies have examined PBL in relation to psychomotor skills in automotive engineering practice [10], [11]. These studies suggest that PBL is relevant to vocational and automotive learning because both contexts require students to connect conceptual knowledge with practical decision-making. Nevertheless, the evidence remains limited regarding how PBL can be implemented iteratively in an automotive engineering course to observe changes in creative thinking indicators across classroom action cycles.

Another issue concerns the assessment of creativity in vocational learning. Technical and vocational education requires assessment approaches that are aligned with practical learning outcomes, observable performance, and workplace-oriented competencies [12]. Therefore, creativity should not only be interpreted as a general learning outcome, but should also be observed through learning activities that require students to generate, compare, justify, and elaborate technical solutions. In this regard, the present study focuses on the implementation of PBL in the Fundamentals of Automotive Engineering course and observes changes in students' creative thinking skills through the indicators of fluency, flexibility, originality, and elaboration. The use of Classroom Action Research allows the learning process to be improved through reflection between cycles, while also providing classroom-based evidence of how students' creative thinking categories change during the intervention.

Based on this background, this study aims to describe the implementation of Problem-Based Learning and examine the observed changes in students' creative thinking skills in the Fundamentals of Automotive Engineering course. The contribution of this study lies in providing contextual evidence from automotive engineering education on how PBL can be applied through Classroom Action Research to support the development of creative thinking skills. This study does not claim causal effectiveness in a broad sense because it involves one class without a comparison group. Instead, it offers process-based evidence of changes in students' creativity categories and learning behaviour across action cycles in a vocational automotive learning context.

METHOD

This study employed a Classroom Action Research (CAR) design to support the improvement of students' creative thinking skills through the implementation of Problem-Based Learning (PBL). CAR was selected because it allows instructional improvement to be carried out in iterative cycles of planning, implementation, observation, and reflection within the actual classroom context [8]. As illustrated in Figure 1, the methodological flow began with study conceptualisation and design, followed by population and sample selection, instrument preparation, and the implementation of two CAR cycles. Each cycle included planning and problem orientation, implementation of the PBL intervention, data collection, data analysis, and reflection. The cycle could be terminated once the success criteria had been met; otherwise, the findings from reflection were used as the basis for improvement in the subsequent cycle.

The study was conducted in the Fundamentals of Automotive Engineering course in the D3 Automotive Engineering programme. The population comprised all students in the automotive engineering programme, while the sample was selected through purposive sampling, namely one class consisting of 21 students identified as relevant to the research objective [14]. These students were organised into five heterogeneous groups, each consisting of four to five members, to support collaborative learning and group-based problem solving during the intervention.

The intervention was carried out over two cycles, and each cycle consisted of two 100-minute sessions. The learning activities followed the core PBL stages commonly applied in vocational learning contexts [10], [13]. These stages included problem orientation, organising students for learning, individual and group investigation, solution development and presentation, and analysis and evaluation of the solution process. In practice, students were first introduced to contextual automotive-related problems, then guided to discuss the problem, explore possible solutions individually and collaboratively, present their proposed solutions, and reflect on both the quality of the solution and the problem-solving process. This sequence was intended to create learning conditions that encouraged active participation, idea generation, and collaborative inquiry.

Data were collected using two instruments: a creative thinking skills questionnaire and observation sheets. The questionnaire was designed to measure students' creative thinking skills using a five-point Likert scale, which remains widely used in educational research because it enables structured measurement of perceptions and observed tendencies [15]. The instrument consisted of 20 items, with five items allocated to each indicator. Based on the current study documents and the uploaded flowchart, the four indicators comprised fluency, flexibility, originality, and evaluation. Observation sheets were used to record the implementation of learning activities and students' participation during the PBL process. The use of observation-based assessment is relevant in technical and vocational education because it helps capture behavioural and performance-related aspects of learning that may not be fully reflected through written responses alone [12]. In addition, the use of indicators such as fluency, flexibility, originality, and elaboration/evaluation in creative thinking assessment is consistent with recent work on creative thinking instrument design [16].

Data analysis was conducted using descriptive percentage analysis. Questionnaire responses were converted into percentage scores based on the completed instrument sheets, and higher percentages indicated stronger observed levels of creative thinking. The percentage scores were then classified into five categories using the criteria adopted in the study, namely: Very Creative: ≥ (Mi + 1.5 SDi); Creative: (Mi + 0.5 SDi) to < (Mi + 1.5 SDi); Fairly Creative: (Mi − 0.5 SDi) to < (Mi + 0.5 SDi); Least Creative: (Mi − 1.5 SDi) to < (Mi − 0.5 SDi); and Not Creative: ≤ (Mi − 1.5 SDi). These categories were used to describe changes in students' creative thinking levels across cycles. The observation data were analysed descriptively to examine student participation and the quality of learning implementation during each cycle.

The success of the intervention was evaluated through the reflection stage at the end of each cycle. The criteria for success were defined as: (1) an increase in the average creative thinking score across the four indicators, (2) improved active participation during group discussions and classroom activities, and (3) the achievement of a "good" category in the learning observation results. When these criteria had not yet been achieved, the results of reflection were used to revise the next cycle. When the criteria were fulfilled, the action research process was terminated and followed by final reporting, as shown in Figure 1.

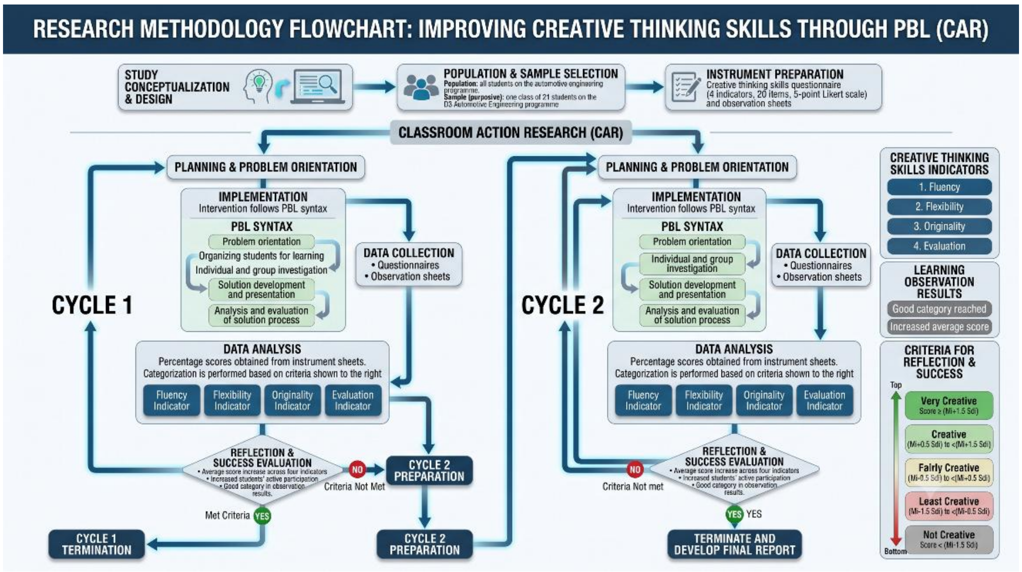

Figure 1. Flowchart of the Classroom Action Research procedure for improving students' creative thinking skills through Problem-Based Learning.

RESULTS AND DISCUSSION

Pre-cycle

At the beginning of the study, the researchers conducted observations and interviews with the lecturers teaching the course. The interviews indicated that, although various learning approaches had been used, such as independent learning, group work, and assignment-based activities, students' creative thinking skills were still relatively low. This condition was reflected in the students' assignment results. Based on these initial findings, the researchers, in collaboration with the course lecturers, decided to implement Problem-Based Learning (PBL) in the Fundamentals of Automotive Engineering course.

The pre-cycle data were used to describe students' initial level of creative thinking before the implementation of PBL. The complete distribution of the pre-cycle data is presented in Table 1.

Table 1. Pre-cycle Creativity Data

Category	Respondents	Percentage
Very Creative	1	4.76%
Creative	6	28.57%
Fairly Creative	11	52.38%
Least Creative	3	14.29%
Not Creative	0	0.00%
Total	**21**	**100%**

As shown in Table 1, most students were initially classified in the Fairly Creative category, accounting for 52.38% of the sample. This was followed by the Creative category at 28.57%, the Least Creative category at 14.29%, and the Very Creative category at 4.76%. No students were classified in the Not Creative category. The same distribution is presented visually in Figure 2, which provides a clearer comparison across categories.

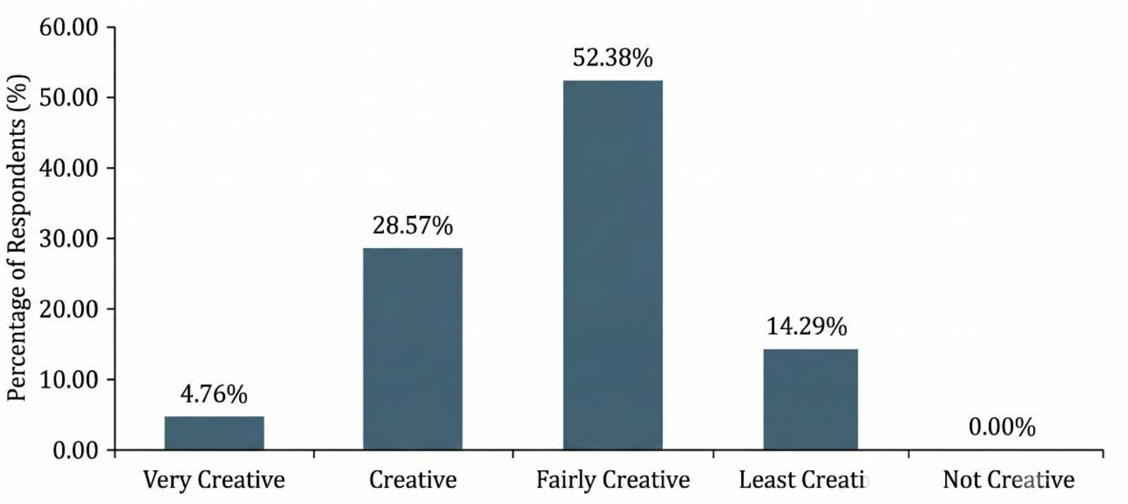

Figure 2. Histogram of Pre-cycle Creativity Data

Cycle I

The results of Cycle I after the implementation of Problem-Based Learning are presented in Table 2.

Table 2. Creativity Data for Cycle I

Category	Respondents	Percentage
Very Creative	3	14.29%
Creative	9	42.86%
Fairly Creative	8	38.10%
Least Creative	1	4.76%
Not Creative	0	0.00%
Total	**21**	**100%**

Based on Table 2, the distribution of creativity levels changed during Cycle I. The largest proportion of students was found in the Creative category at 42.86%, followed by the Fairly Creative category at 38.10%. The proportion of students in the Very Creative category increased to 14.29%, while the Least Creative category decreased to 4.76%. No students were classified in the Not Creative category. These results indicate a shift in the distribution of students' creative thinking levels compared with the pre-cycle condition. The distribution for Cycle I is also illustrated in Figure 3.

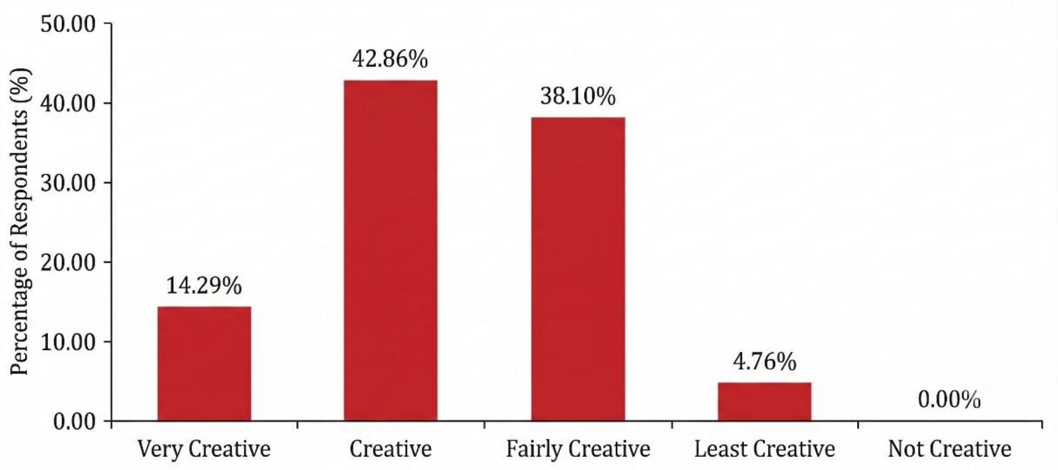

Figure 3. Histogram of Creativity Data for Cycle I

In addition to the distribution shown in Table 2 and Figure 3, the observations conducted during Cycle I indicated that several aspects still required improvement. Some students still experienced difficulty in generating varied alternative solutions to the automotive problems provided. Group discussions also tended to be dominated by only a few members, while some students were still dependent on lecturer guidance during the investigation and decision-making process. These observations formed the basis for revising the learning implementation in Cycle II.

Cycle II

Based on the reflection results from Cycle I, several adjustments were introduced in Cycle II. The lecturers presented problems that were more contextual and more closely related to students' experiences, strengthened the scaffolding process through prompting questions, clarified the division of roles within groups to support more balanced participation, and provided more intensive feedback during investigation and discussion. Students were also encouraged to compare several technical alternatives before selecting the most appropriate solution. The results of Cycle II are presented in Table 3.

Table 3. Creativity Data for Cycle II

Category	Respondents	Percentage
Very Creative	6	28.57%
Creative	10	47.62%
Fairly Creative	5	23.81%
Least Creative	0	0.00%
Not Creative	0	0.00%
Total	**21**	**100%**

As presented in Table 3, the distribution of students' creativity levels changed again in Cycle II. The Creative category represented the highest proportion at 47.62%, followed by the Very Creative category at 28.57%, and the Fairly Creative category at 23.81%. No students were classified in either the Least Creative or Not Creative categories. Compared with the previous stage, the results of Cycle II show a further shift in the distribution toward the higher creativity categories. This distribution is also shown in Figure 4.

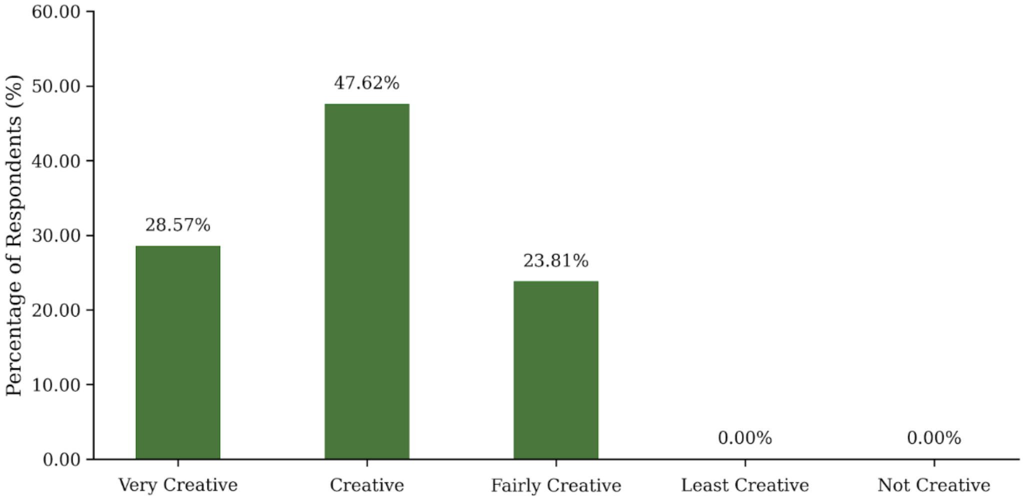

Figure 4. Histogram of Creativity Data for Cycle II

Overall, the results across the three stages show changes in the distribution of students' creative thinking categories from the pre-cycle condition to Cycle I and then to Cycle II. The proportion of students in the Very Creative and Creative categories increased across cycles, while the proportion of students in the Least Creative category decreased from 14.29% in the pre-cycle stage to 4.76% in Cycle I and 0.00% in Cycle II. Likewise, no students were classified in the Not Creative category in either Cycle I or Cycle II.

Discussion

The results show a gradual shift in students' creative thinking categories from the pre-cycle stage to Cycle I and Cycle II. This shift should be interpreted as an observed classroom improvement within the Classroom Action Research framework rather than as statistical evidence of causal effectiveness. The pattern indicates that the implementation of Problem-Based Learning (PBL), supported by reflection and instructional refinement across cycles, was associated with a higher proportion of students in the Creative and Very Creative categories. This interpretation is aligned with the rationale of PBL as a student-centered learning model and with vocational learning principles that emphasize authentic problem solving, collaborative learning, and performance-oriented assessment [5], [10], [12].

The improvement across cycles is summarized in Table 4. This table does not present new data but reorganizes the results from the pre-cycle, Cycle I, and Cycle II to make the development of students' creative thinking categories easier to interpret.

Table 4. Changes in students' creative thinking categories across research stages

Stage	Very Creative	Creative	Fairly Creative	Least Creative	Not Creative
Pre-cycle	4.76%	28.57%	52.38%	14.29%	0.00%
Cycle I	14.29%	42.86%	38.10%	4.76%	0.00%
Cycle II	28.57%	47.62%	23.81%	0.00%	0.00%

Based on Table 4, the proportion of students in the Very Creative category increased from 4.76% in the pre-cycle to 14.29% in Cycle I and 28.57% in Cycle II. The Creative category also increased from 28.57% in the pre-cycle to 42.86% in Cycle I and 47.62% in Cycle II. At the same time, the Fairly Creative category decreased from 52.38% to 23.81%, while the Least Creative category decreased from 14.29% to 0.00%. The trend displayed in Figure 5 visually reinforces this movement from lower creativity categories toward higher creativity categories across the two action cycles.

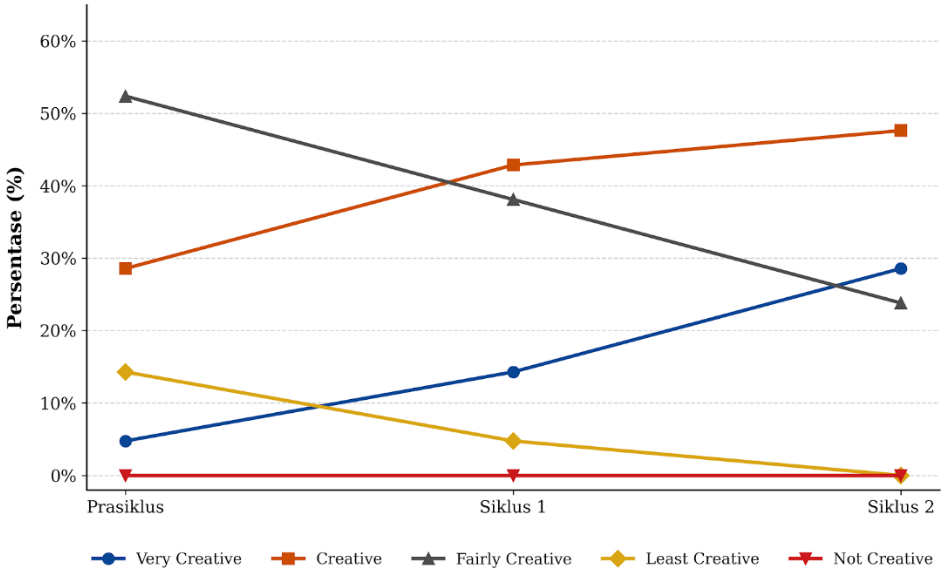

Figure 5. Trend of students' creative thinking category changes from pre-cycle to Cycle II

The observed improvement can be explained through the learning structure used in the PBL intervention. In Cycle I, students were introduced to contextual automotive problems and were required to identify possible causes, discuss alternatives, and present solutions. However, the reflection results showed that some students still had difficulty generating varied ideas, and group discussions were still dominated by several members. Similar classroom-based PBL research has shown that the development of critical and creative thinking depends not only on the presence of problems but also on how students are guided through discussion, investigation, and reflection [17]. Therefore, the improvements introduced in Cycle II, such as more contextual problems, clearer group roles, prompting questions, and more intensive feedback, were important because they provided more structured opportunities for students to participate and develop their ideas.

The increase in the Creative and Very Creative categories suggests that PBL can create a learning environment that encourages students to produce and refine ideas during technical problem-solving activities. This finding extends previous evidence from student-centered PBL environments showing that problem-based activities can support creative thinking when learners are required to explore problems, collaborate with peers, develop ideas, and construct solutions rather than merely receive information from the teacher [18]. In the context of this study, the automotive problems functioned as learning triggers that required students to connect conceptual knowledge with practical reasoning. This is important in automotive engineering education because students are expected not only to understand vehicle systems but also to think flexibly when diagnosing problems, selecting technical alternatives, and explaining the logic behind their decisions.

The development of fluency was reflected in students' increasing ability to generate more ideas and possible solutions during group investigation. PBL encourages this process because students are placed in situations where one problem may have more than one possible solution.

Previous studies have reported that PBL supported by scaffolding can make students more active in exchanging ideas, asking questions, and expressing possible solutions during the learning process [19]. This explains why students in this study became more capable of proposing several alternatives after they were given more structured prompts and more contextual problems in Cycle II.

The improvement in flexibility can be interpreted from students' increasing ability to consider different technical approaches before selecting a solution. In the PBL process, students had to examine the problem from several perspectives, compare the possible solutions proposed by group members, and justify why a particular solution was considered more appropriate. Recent research integrating PBL with computational thinking also emphasizes that problem-based activities can stimulate students to analyze problems, test alternative pathways, and construct solutions more creatively [20]. Although the present study was conducted in an automotive course rather than a computational learning context, both studies indicate that the problem-solving structure of PBL can support flexible thinking when students are asked to explore alternatives rather than follow a single fixed answer.

Originality also appeared to develop as students began to propose solutions that were not limited to examples provided by the lecturer. In the solution development and presentation stages, students were required to explain their proposed solutions using technical reasoning. This requirement encouraged them to formulate their own arguments, defend their ideas, and respond to questions from peers. Research on PBL and digital literacy has similarly shown that students' creativity can be supported when they are given opportunities to search for information, discuss findings, and transform information into original responses to a problem [21]. In the present study, originality should still be interpreted cautiously because the assessment was based on classroom observation and category distribution, not on a separate originality test. Nevertheless, the classroom pattern suggests that students became more confident in proposing varied technical ideas during the second cycle.

The elaboration aspect was reflected in students' ability to explain their proposed solutions more systematically and with more detailed reasoning. This improvement can be linked to the presentation and evaluation stages of PBL, where students had to communicate not only what solution they selected but also why the solution was technically reasonable. Similar findings have been reported in studies using PBL-assisted strategies, where creative thinking development was reflected through students' ability to expand ideas, provide supporting explanations, and connect their answers with the problem context [22]. In this study, elaboration became more visible after Cycle II because students received more intensive feedback and were encouraged to compare several technical alternatives before presenting the final solution.

The results of this study are generally consistent with broader research showing that creative thinking can be developed when students are exposed to learning environments that require active inquiry, collaboration, and reflection. A study on 21st-century skills curriculum found that creative thinking development is supported when learning tasks require learners to apply ideas, communicate reasoning, and engage in higher-order thinking processes [23]. Cooperative learning research has also shown that interaction among learners can contribute to creative thinking development because students are exposed to different perspectives and problem-solving strategies [24]. These findings help explain why the group-based structure of PBL in this study was important. The improvement did not occur simply because PBL was used, but because students were repeatedly engaged in problem orientation, investigation, discussion, presentation, and reflection.

However, the interpretation of the findings must remain proportional. The present study used Classroom Action Research with one class of 21 students and did not include a control group. Therefore, the results show improvement across cycles within the studied classroom, but they should not be generalized as definitive causal evidence that PBL alone produced the improvement. Meta-analytic evidence in higher education indicates that PBL can support higher-order thinking development, but the magnitude and consistency of its effects depend on implementation quality, learning context, assessment type, and instructional support [25]. A comparative pedagogical evaluation of PBL and lecture-based methods also suggests that PBL can provide stronger opportunities for cognitive engagement, but its success depends on how well learning activities are structured and facilitated [26]. These findings support a careful interpretation of the present study: PBL was associated with positive changes in students' creative thinking categories, but the improvement was also shaped by the iterative refinement of instruction during the CAR process.

From a practical perspective, this study suggests that PBL can be used as a classroom strategy to support creative thinking in automotive engineering learning when it is implemented through structured cycles, contextual problems, collaborative investigation, and reflective improvement. For lecturers, the findings imply that creative thinking is more likely to develop when students are given space to generate multiple ideas, compare technical alternatives, justify their choices, and receive feedback during the problem-solving process. For automotive vocational education, the study provides classroom-based evidence that authentic technical problems can be used not only to teach automotive content but also to encourage fluency, flexibility, originality, and elaboration in students' thinking. Nevertheless, future studies should involve larger samples, clearer instrument validation, and comparison groups to examine the robustness of these findings beyond the classroom context investigated in this study.

CONCLUSION

This classroom action research showed an observed improvement in students' creative thinking skills after the implementation of Problem-Based Learning in the Fundamentals of Automotive Engineering course. The improvement was reflected in the shift of students' creativity categories across the action cycles, with more students moving into the Creative and Very Creative categories by the end of Cycle II. This development was also observed in students' ability to generate ideas, consider alternative solutions, propose original responses, and elaborate technical reasoning during problem-solving activities and group discussions.

The findings suggest that Problem-Based Learning can support the development of creative thinking skills in automotive engineering learning when implemented through contextual problems, collaborative investigation, presentation, feedback, and reflection. The contribution of this study lies in providing classroom-based evidence of how PBL can be applied iteratively through Classroom Action Research to support creative thinking in a vocational automotive learning context. However, the findings should be interpreted within the limits of a single class, a small sample size, and the absence of a comparison group. Future research should involve larger samples, different vocational education settings, and more robust research designs to further examine students' creative thinking development.

REFERENCES

[1] R. Doni, R. Dinata, A. Permana, H. S. Damanik, and N. Basuki, "Analysis of Automotive Industry Competency Needs for Automotive Engineering Education Students of Medan State University in the 4.0 Era," AEEJ: Journal of Automotive Engineering and Vocational Education, vol. 6, no. 1, pp. 33–42, 2025, doi: 10.24036/aeej.v6i1.278.

[2] W. Purwanto, H. D. Saputra, D. S. Putra, Z. Abadi, A. A. Arif, and I. W. Kustanrika, "Improving Student Achievement with the Application of Smart Trainers Integrated QR Code," AEEJ:

Journal of Automotive Engineering and Vocational Education, vol. 6, no. 2, pp. 73–80, 2025, doi: 10.24036/aeej.v6i2.249.

[3] A. S. Zalman, I. Y. Basri, Andrizal, and Muslim, "Perancangan Video Pembelajaran Sistem Kelistrikan Bodi Kendaraan Pada Mata Pelajaran Pemeliharaan Kelistrikan Kendaraan Ringan," AEEJ: Journal of Automotive Engineering and Vocational Education, vol. 4, no. 2, pp. 103–112, 2023, doi: 10.24036/aeej.v4i2.195.

[4] A. T. Aldossari, "Creative Thinking Skills Included in the Content of Evaluation Questions in the Curricula of the Kingdom of Saudi Arabia," International Journal of Education and Practice, vol. 9, no. 3, pp. 520–531, 2021, doi: 10.18488/journal.61.2021.93.520.531.

[5] A. Handayani and H. D. Koeswanti, "Meta-Analisis Model Pembelajaran Problem Based Learning (PBL) Untuk Meningkatkan Kemampuan Berpikir Kreatif," Jurnal Basicedu, vol. 5, no. 3, pp. 1349–1355, 2021, doi: 10.31004/basicedu.v5i3.924.

[6] I. P. Ningrum and R. Marsinun, "Penerapan Model Pembelajaran Problem Based Learning untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa," Jurnal Basicedu, vol. 6, no. 5, pp. 8205–8214, 2022, doi: 10.31004/basicedu.v6i5.3784.

[7] F. Hidayati, A. Solida, and E. Wisudariani, "Pengaruh Pembelajaran Problem Based Learning Dalam Meningkatkan Kreativitas Dan Kemampuan Berfikir Kritis Mahasiswa: The Effect of Problem-Based Learning in Increasing Students' Creativity and Critical Thinking Ability," BIODIK, vol. 10, no. 2, pp. 46–53, 2024, doi: 10.22437/biodik.v10i2.29854.

[8] A. Safitri, H. Chotimah, A. M. Hudha, and A. Rahardjanto, "Application of Problem-Based Learning to Improve Problem Solving Skills and Creative Thinking Skills of Class XI Students," Jurnal Eksakta Pendidikan, vol. 7, no. 2, pp. 157–170, 2023, doi: 10.24036/jep/vol7-iss2/757.

[9] L. D. Saputri and D. Puspasari, "Does Problem-Based Learning Enhance Student Creativity?," Jurnal Pendidikan Ekonomi, vol. 18, no. 2, pp. 160–170, 2025, doi: 10.17977/UM014v18i2p160.

[10] H. Maksum, W. Purwanto, S. Siman, D. Ampera, D. Yuvenda, and H. Hasan, "Improving Problem-Solving and Communication Skills in Automotive Vocational Education through the Development of Teaching Factory Model with Problem-Based Learning (TEFA-PBL) Concept," International Journal of Education in Mathematics, Science and Technology, vol. 12, no. 2, pp. 364–386, 2024, doi: 10.46328/ijemst.3941.

[11] I. Yuliady, Z. Fadli, Rahmadani, Y. D. Alfana, and E. Fernandes, "The Influence of Problem Base Learning Model on Improving Psychomotor Abilities of Automotive Engineering," Jurnal Vokasi Mekanika, vol. 8, no. 1, pp. 44–52, 2026, doi: 10.24036/29ry5075.

[12] S. R. M. Yusop, M. S. Rasul, R. M. Yasin, H. U. Hashim, and N. A. Jalaludin, "An Assessment Approaches and Learning Outcomes in Technical and Vocational Education: A Systematic Review Using PRISMA," Sustainability, vol. 14, no. 9, Art. no. 5225, 2022, doi: 10.3390/su14095225.

[13] M. Akhyar, F. Ihsan, S. Suharno, A. G. Tamrin, and Purwanto, "Development of Problem and Project-Based Learning Syntax to Improve Vocational Student Learning Outcomes," *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 30, no. 1, pp. 1–19, 2024, doi: 10.21831/jptk.v30i1.53968.

[14] M. Ahmad and S. Wilkins, "Purposive Sampling in Qualitative Research: A Framework for the Entire Journey," *Quality & Quantity*, early access, Dec. 2024, doi: 10.1007/s11135-024-02022-5.

[15] I. Kusmaryono, D. Wijayanti, and H. R. Maharani, "Number of Response Options, Reliability, Validity, and Potential Bias in the Use of the Likert Scale Education and Social

Science Research: A Literature Review," *International Journal of Educational Methodology*, vol. 8, no. 4, pp. 625–637, 2022, doi: 10.12973/ijem.8.4.625.

[16] A. Maqruf, A. Suhandi, A. Samsudin, M. Sözbilir, H. Ö. Kapıcı, H. Nasbey, and E. Nugraha, "Exploring Students' Creative Thinking Skills: A Design of Reliable Instrument in Term of Assessing Creative Thinking on Temperature and Heat Concepts," *Journal of Natural Science and Integration*, vol. 8, no. 2, pp. 258–272, 2025, doi: 10.24014/jnsi.v8i2.31857.

[17] Kardoyo, A. Nurkhin, Muhsin, and H. Pramusinto, "Problem-Based Learning Strategy: Its Impact on Students' Critical and Creative Thinking Skills," European Journal of Educational Research, vol. 9, no. 3, pp. 1141–1150, 2020, doi: 10.12973/eu-jer.9.3.1141.

[18] C. B. Ates and H. Aktamis, "Investigating the Effects of Creative Educational Modules Blended with Cognitive Research Trust (CoRT) Techniques and Problem-Based Learning (PBL) on Students' Scientific Creativity Skills and Perceptions in Science Education," Thinking Skills and Creativity, vol. 51, Art. no. 101471, 2024, doi: 10.1016/j.tsc.2024.101471.

[19] M. D. W. Ernawati, Yusnidar, Haryanto, E. F. S. Rini, F. T. Aldila, T. Haryati, and R. Perdana, "Do Creative Thinking Skills in Problem-Based Learning Benefit from Scaffolding?," Journal of Turkish Science Education, vol. 20, no. 3, pp. 399–417, 2023, doi: 10.36681/tused.2023.023.

[20] W. Ji and G. K. W. Wong, "Integrating Problem-Based Learning and Computational Thinking: Cultivating Creative Thinking in Primary Education," Frontiers in Education, vol. 10, Art. no. 1625105, 2025, doi: 10.3389/feduc.2025.1625105.

[21] I. T. Simangunsong, D. D. Panggabean, and D. P. Damanik, "Problem-Based Learning to Enhance Students' Creativity through Digital Literacy," Journal on Education, vol. 5, no. 2, pp. 5231–5237, 2023, doi: 10.31004/joe.v5i2.1143.

[22] F. Ramadhani and K. Khairuna, "The Effect of Fishbone-Assisted Problem-Based Learning Model on Students' Creative Thinking Skills in Biology," Jurnal Basicedu, vol. 6, no. 5, pp. 8405–8413, 2022, doi: 10.31004/basicedu.v6i5.3840.

[23] A. Dilekçi and H. Karatay, "The Effects of the 21st Century Skills Curriculum on the Development of Students' Creative Thinking Skills," Thinking Skills and Creativity, vol. 47, Art. no. 101229, 2023, doi: 10.1016/j.tsc.2022.101229.

[24] R. Segundo-Marcos, A. M. Carrillo, V. L. Fernández, and M. T. Daza González, "Age-Related Changes in Creative Thinking during Late Childhood: The Contribution of Cooperative Learning," Thinking Skills and Creativity, vol. 49, Art. no. 101331, 2023, doi: 10.1016/j.tsc.2023.101331.

[25] Y. Liu and A. Pásztor, "Effects of Problem-Based Learning Instructional Intervention on Critical Thinking in Higher Education: A Meta-Analysis," Thinking Skills and Creativity, vol. 45, Art. no. 101069, 2022, doi: 10.1016/j.tsc.2022.101069.

[26] F. Ssemugenyi and A. Hung, "Teaching and Learning Methods Compared: A Pedagogical Evaluation of Problem-Based Learning (PBL) and Lecture Methods in Developing Learners' Cognitive Abilities," Cogent Education, vol. 10, no. 1, Art. no. 2187943, 2023, doi: 10.1080/2331186X.2023.2187943.