Bridging theory and practice: Implementation of hybrid motorcycle prototypes as learning media in vocational automotive education

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Abstract: Rapid advancements in hybrid vehicle technology demand significant adjustments in vocational education to equip students with relevant competencies. This study investigates the effectiveness of a hybrid motorcycle prototype as an innovative learning media to improve student learning outcomes in vocational automotive education. Employing a pre-experimental one-group pretest-post-test design, the research involved 30 Grade XI Automotive Engineering students at SMK Negeri 1 Cisarua. Participants underwent a pretest, followed by four prototype-based learning sessions, and a post-test. Data were analysed using descriptive statistics, paired-samples t-test, and normalized gain (g). Results demonstrated a substantial improvement in learning outcomes, with the mean score increasing from 58.5 to 82.67 (mean gain = 24.17 points; $t(29) = 8.805$, $p < 0.001$; Cohen's $d = 1.61$), indicating a very large effect size. The normalized gain of 0.55 suggests medium effectiveness based on Hake's classification. Furthermore, 90.0% (27/30) of students achieved scores ≥75 post-intervention, compared to 23.3% (7/30) beforehand. Aligning with Edgar Dale's Cone of Experience, these findings highlight that direct, hands-on engagement enhances comprehension and retention. The study concludes that hybrid motorcycle prototypes offer a cost-effective, practical, and scalable solution to bridge the theory-practice gap in vocational automotive education, especially in motorcycle-dominant contexts. Recommendations include integrating prototype-based learning into the Merdeka Curriculum and expanding its application to other technical domains.

Keywords: hybrid motorcycle; vocational education; learning outcomes; automotive technology; learning media

1. Introduction

Indonesia remains one of the world's largest two-wheelers markets, with domestic motorcycle sales reaching ~6.33 million units in 2024, underscoring the centrality of motorcycles in everyday mobility. At the same time, electrification of two-and-three-wheelers (2/3Ws) is advancing across Asia; in 2024 Indonesia sold ~105,000 electric 2Ws, yet the electric share stayed below 2%, indicating a sizeable readiness gap in skills and training for electrified powertrains (International Energy Agency, 2025; *Penjualan Motor Di Indonesia Tahun 2024 Tembus 6,3 Juta Unit*, n.d.). Policy and curriculum alignment. The Merdeka Curriculum explicitly lists maintenance and repair of electric and hybrid motorcycles as target competencies for upper secondary vocational programs (Fase F), which compels schools to adopt authentic media that concretize concepts such as power flow, energy recovery, and dual propulsion control. Instructional response and research gap. Hands-on media, particularly working prototypes, have repeatedly outperformed passive or purely demonstrative tools in TVET contexts, delivering higher comprehension and transfer of learning

compared to lectures, slides, or static trainers (Ramdhani et al., 2024; Ravi et al., 2024; Yahya et al., 2024). However, most prior class resources centre on EVs or four-wheel hybrids, with limited evidence on hybrid motorcycle media tailored to two-wheelers dominant settings. Our study addresses this gap by implementing a hybrid motorcycle prototype and quantifying its effectiveness with pre/post testing, effect sizes, and normalized gains. The rapid advancement of automotive technology, especially hybrid vehicle systems, demands substantial adaptation in vocational education curricula so students acquire industry-relevant competencies (Hardiyanta et al., 2024). Hybrid technology, which integrates an internal combustion engine with one or more electric motors to improve energy efficiency and reduce emissions, represents a paradigm shift in transportation (Iskandar & Yulanto, 2021; Rojas-Reinoso et al., 2025).

Despite these advances, practice often lags. A preliminary study at SMK Negeri 1 Cisarua showed that only 33.3% of Grade XI students met the minimum competency standard in hybrid-system learning (KKM = 75), with an average class score of 67, indicating insufficient understanding, largely due to limited learning media that fail to bridge theory and practice. The challenge is compounded by conventional methods (e.g., lectures and videos) that provide little hands-on engagement, underscoring the need for richer instructional media tailored to technical subjects (Effendi & Yoto, 2024; Lesmana et al., 2023). This is consistent with broader findings: curriculum and media limitations in many SMKs hinder higher-order thinking and deep comprehension. Consequently, state-of-the-artwork in TVET stresses hands-on media aligned with Industry 4.0 requirements. The literature highlights the importance of interactive, practice-oriented resources and updated curricular support to keep pace with emerging automotive technologies (Ramdhani et al., 2024; Ravi et al., 2024).

Among available alternatives, prototype-based learning media are especially promising. Unlike simulators that only visualize processes or static trainer boards that limit exploration, a working prototype affords safe, direct, and representative experiences with real components and behaviours (Dwivedi et al., 2022). Empirical results show sizeable gains when classes use prototypes compared to trainer media or lecture-only approaches (Iskandar & Yulanto, 2021; Ramdhani et al., 2024; Yahya et al., 2024). Yet, most previous research focuses on electric vehicles or theoretical treatments of hybrid systems, with limited attention to hands-on media specifically designed for hybrid motorcycles, particularly in Indonesia's two-wheeler-dominant context. This study addresses that gap by evaluating a hybrid motorcycle prototype as a learning media in vocational education, providing empirical evidence on its effectiveness in improving student understanding of dual-propulsion systems (Iskandar & Yulanto, 2021; Rojas-Reinoso et al., 2025).

The novelty of this research lies in developing and implementing a hybrid motorcycle prototype tailored to Indonesian vocational settings, offering a culturally appropriate and cost-effective approach to hybrid education. It contributes theoretically to experiential learning in TVET and practically to curriculum development through authentic, hands-on engagement with hybrid components (Ramdhani et al., 2024; Ravi et al., 2024). The urgency is reinforced by the growing demand for technicians skilled in hybrid technologies and the policy direction of the Merdeka Curriculum for SMKs, which explicitly includes maintenance and repair of electric and hybrid motorcycles, necessitating effective learning media to convey complex concepts and ensure student readiness for evolving industry needs. Grounded in experiential learning perspectives, including Dale's Cone of Experience and prior work on electric motorcycle trainers to eliminate misconceptions, this study examines how a hybrid motorcycle prototype can turn abstract concepts into tangible learning experiences and enhance both conceptual and practical competencies needed by industry (Ramdhani et al., 2024). Accordingly, this study investigates the implementation of a

hybrid motorcycle prototype as learning media to enhance student outcomes in vocational high schools. The objectives are to: (i) measure learning outcomes before and after prototype implementation using pre- and post-tests, (ii) analyse the statistical significance of gains using paired-samples t-tests, and (iii) evaluate the practical effectiveness of the prototype as an innovative learning media in Indonesian TVET contexts.

2. Methods

2.1 Research design

This study employed a quantitative approach with a pre-experimental one-group pretest-post-test design. While this design has limitations regarding causal inference due to the absence of a control group, it was chosen due to ethical considerations in educational settings where withholding potentially beneficial interventions from students would be inappropriate. The design allowed for the measurement of learning outcome changes within the same group before (pretest) and after (post-test) the intervention. While acknowledging the limitations of a one-group pretest-post-test design in establishing causality, this approach was deemed appropriate for evaluating the practical effectiveness of a novel learning medium within an authentic classroom setting, where random assignment to control groups was not feasible or ethically desirable due to the need for equitable learning opportunities.

2.2 Location, participants, and research setting

The research was conducted within the Motorcycle Engineering subject at SMK Negeri 1 Cisarua. The sample size of 30 participants was determined based on practical classroom constraints and statistical requirements for paired t-tests. Post-hoc power analysis confirmed adequate power (>0.80) to detect medium to large effect sizes, which was appropriate given the nature of the educational intervention. Accordingly, the study employed a one-group pretest–post-test design, as summarized in Table 1.

Table 1. One-group pretest–post-test design

Group	Pretest (O1)	Treatment (X)	Post-test (O2)
Experiment	Initial test of cognitive learning outcomes	Implementation of the hybrid motorcycle prototype as a learning media	Final test of learning outcomes

2.3 Research procedure

The research implementation was divided into three main meetings, encompassing a total of four distinct prototype-based learning sessions as shown at Figure 1. The first meeting began with a brief introduction, statement of objectives, and key material on hybrid systems, followed by the pretest. The second meeting focused on guided observation of the prototype, diagnosis of symptoms and maintenance according to Standard Operating Procedures (SOP), and group discussions with teacher guidance. The third meeting was used for concept consolidation, group work presentations, and the post-test as the final assessment. After the post-test, data were compiled for analysis. These three meetings encompassed a total of four distinct prototype-based learning sessions, with the first meeting focusing on initial material and pretest, and the subsequent two meetings dedicated to hands-on engagement with the prototype. Details of the learning implementation schedule are provided in Table 2.

Table 2. Learning implementation schedule

Meeting	Activity focus	Assessment component
1	Introduction, objectives, key material on the hybrid system; pretest conducted after a brief presentation	Pretest
2	Prototype observation, symptom diagnosis, maintenance according to SOP, structured discussion	Performance & participation
3	Concept consolidation, group presentation, concept reinforcement; post-test at the end of the meeting	Post-test

2.4 Research instruments and validity

Cognitive learning outcomes were measured using a 20-item multiple-choice test on a 0–100 scale. The test items were aligned with Bloom's Taxonomy levels C2–C4 (comprehension–application–analysis) and competency indicators for hybrid system material (power flow, components/functions, regenerative braking, maintenance/diagnosis procedures). Content validity of the test items and learning media was established through expert judgment. This involved two media experts who assessed the feasibility of the learning instruments, and two experts with an academic background in automotive engineering education who validated the pretest and posttest questions, ensuring alignment with curriculum objectives and Bloom's Taxonomy levels. The internal reliability of the 20-item multiple-choice test was assessed using Cronbach's Alpha, yielding a coefficient of 0.85, indicating high internal consistency and suitability for classroom assessment.

2.5 Data collection techniques

Data were collected through written pretest and post-test to measure cognitive learning outcomes. Classroom documentation (activity photos, worksheets, and field notes) was used as supplementary material to confirm the intervention's implementation and learning context.

2.6 Data analysis

Assumptions were assessed using Shapiro–Wilk (pre: p=.226; post: p=.059). With normality satisfied, a paired-samples t-test compared pre- and post-intervention means at α=.05. Learning effectiveness was quantified using (i) class mean N-Gain and its categorical distribution and (ii) paired effect sizes: cohen's $d_z = t/\sqrt{n}$ and Hedge's $g_{av} = J \,.\, d_{av}$ with $SD_{av} = \sqrt{(SD_{pre}^2 + SD_{post}^2)/2}$ and $J = \frac{3}{4(n-1)-1}$. Confidence intervals used standard large-sample approximations with the observed pre–post correlation. Details of the N-Gain classification rubric are provided in Table 3.

Table 3. N-gain score categories

g Score	Category
$0.70 < g \leq 1.00$	High
$0.30 \leq g \leq 0.70$	Medium
$0.00 < g < 0.30$	Low
$g = 0.00$	No Improvement
$-1.00 < g < 0.00$	Decline

2.7 Intervention implementation

Intervention implementation was evidenced through process documentation from all three meetings and teacher notes. The 20-item test blueprint (levels C2–C4) and performance & participation rubrics for practical activities are provided as separate appendices, accessible to editors/reviewers as per journal requirements.

3. Results

Student's post-test scores (M = 82.67, SD = 9.07) were higher than pretest (M = 58.50, SD = 17.43), mean difference = 24.17, t(29) = 8.805, $p < .001$, 95% CI [18.55, 29.78]. The improvement was very large ($d_z = 1.61$; $g_{av} = 1.69$). Normalized gain averaged 0.55 (medium). The share of students achieving KKM ≥ 75 rose from 23.3% (7/30) to 90.0% (27/30). Minimum–maximum scores changed from 30–90 (pre) to 60–95 (post). The research was successfully conducted over a five-week period from July to August 2025 at SMK Negeri 1 Cisarua, West Bandung Regency. All planned research activities were completed according to the predetermined timeline, with 30 participants from Grade XI Automotive Engineering class TO-2 completing the full intervention protocol. The implementation achieved a 100% participant retention rate, with no dropouts during the study period. Participants were Grade XI students with an average age of 17 years. All participants were male, reflecting the typical gender distribution in automotive engineering programs in Indonesia. Based on a preliminary questionnaire, 40% of students had prior informal automotive experience (e.g., assisting at a family-owned workshop), while 60% had no prior experience outside of formal school subjects. This distribution allowed for an exploratory analysis of the prototype's effectiveness across different experience levels.

3.1 Pretest and post-test score analysis

Descriptive analysis of the pretest and post-test scores revealed a significant improvement in student learning outcomes following the intervention. The mean pretest score was M=58.50 (SD=17.43), while the mean post-test score increased to M=82.67 (SD=9.07). This represents a mean gain of 24.17 points. The minimum score increased from 30 to 60, and the maximum score increased from 90 to 95. The complete descriptive statistics are presented in Table 4.

Table 4. Descriptive statistics of pretest and post-test scores

Statistic	Pretest	Post-test
N	30	30
Mean	58.50	82.67
Median	60.00	85.00
Std. Deviation	17.43	9.07
Minimum	30	60
Maximum	90	95

3.2 Normal test results

The Shapiro-Wilk test was used to assess the normality of the pretest and posttest score distributions. The results indicated that both the pretest ($W(30) = 0.954$, $p = 0.226$) and post-test ($W(30) = 0.940$, $p = 0.059$) scores were normally distributed ($p > 0.05$), satisfying the assumption for the paired-samples t-test.

3.3 Paired-samples T-test

A paired-samples t-test showed a statistically significant increase from pretest (M = 58.50, SD = 17.43) to posttest (M = 82.67, SD = 9.07), t(29) = 8.805, $p < .001$, mean difference = 24.17, 95% CI [18.55, 29.78]. The effect was very large (d_z = 1.61; g_av = 1.69). Normalized gain averaged 0.55 (medium). The share of students achieving KKM ≥ 75 rose from 23.3% (7/30) to 90.0% (27/30). Minimum–maximum scores changed from 30–90 (pre) to 60–95 (post).

3.4 Normalized gain (N-Gain) analysis

The normalized gain (N-Gain) was calculated to measure the effectiveness of the learning intervention. The average N-Gain for the class was 0.55, which falls into the "medium" effectiveness category according to Hake's classification. Individual N-Gain distribution showed: 7 students (23.3%) achieved high gains ($g > 0.70$), 20 students (66.7%) achieved medium gains ($0.30 \leq g \leq 0.70$), 2 students (6.7%) achieved low gains ($g < 0.30$), and 1 student (3.3%) showed no improvement. As shown in Table 5, most students achieved medium gains, with smaller proportions in the high, low, and no-improvement groups.

Table 5. N-Gain score distribution

N-Gain Category	Frequency	Percentage (%)
High ($g > 0.70$)	7	23.3
Medium ($0.30 \leq g \leq 0.70$)	20	66.7
Low ($g < 0.30$)	2	6.7
No improvement ($g = 0$)	1	3.3
Total	**30**	**100**

3.5 Minimum Competency Standard (MCS) achievement

Analysis of KKM achievement showed a significant improvement after the intervention (Figure 2). Before the intervention, 23.3% of students (7 out of 30) achieved the KKM ≥ 75. After the intervention, 90% of students (27 out of 30) successfully achieved the KKM. This demonstrates the practical effectiveness of the prototype in helping students meet the required competency standards.

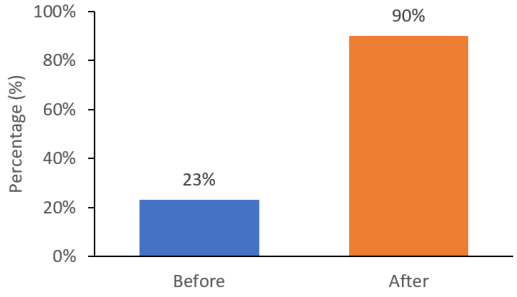

Figure 2. Comparison of KKM (≥75) before (23.3%) vs after (90.0%)

3.6 Effect size analysis

Cohen's d was calculated to determine the practical significance of the intervention. The effect size was $d_z \approx 1.61; g_{av} \approx 1.69$ (both large), indicating a very large effect according to Cohen's

conventions (1988), where d = 0.8 represents a large effect. This suggests that the hybrid motorcycle prototype intervention not only achieved statistical significance but also demonstrated substantial practical importance. The significant increase in mean scores from pretest to posttest clearly indicates a positive impact of the hybrid motorcycle prototype-based learning on students' cognitive learning outcomes.

4. Discussion

The very large, paired effect sizes (e.g., $d_z \approx 1.61; g_{av} \approx 1.69$) and the class mean N-Gain (0.55, medium) indicate substantial practical significance of the prototype-based approach beyond statistical significance. Improvements are consistent with experiential learning mechanisms in vocational settings, where direct manipulation of hybrid components promotes concept consolidation and transfer. Furthermore, the significant increase in the percentage of students achieving the minimum competency standard (KKM = 75) from 23.3% (7/30) to 90.0% (27/30) post-intervention highlights the practical success of this learning approach in preparing students for industry standards. These results underscore that direct, hands-on engagement with functional prototypes can effectively transform abstract theoretical concepts into tangible, comprehensible learning experiences, aligning with Edgar Dale's Cone of Experience which emphasizes the importance of active participation for deeper learning and retention.

Our findings align with prior work showing sizeable gains with prototype-based learning in vocational contexts (Yahya et al., 2024) and extend evidence to hybrid motorcycles in two-wheeler-dominant settings. Yahya et al. (2024) findings on the superior learning improvement achieved through prototype utilization compared to traditional methods. This research further contributes to the existing body of knowledge by specifically addressing the significant gap in empirical investigations of hands-on learning media for hybrid motorcycles within the Indonesian vocational education context. While previous studies often focused on four-wheeled hybrid vehicles or theoretical approaches, our study provides unique evidence for two-wheeled hybrid systems, which are highly relevant in motorcycle-dominant regions. The practical implications of this study are significant for vocational automotive education, particularly in developing countries with high motorcycle usage. The hybrid motorcycle prototype offers a cost-effective, practical, and scalable solution to bridge the theory-practice gap, enabling students to develop essential competencies for the evolving automotive industry. Integrating such prototype-based learning into the Merdeka Curriculum can provide vocational high schools with a powerful tool to enhance student engagement, improve learning outcomes, and ensure graduates are well-prepared for the demands of the modern automotive market. Theoretically, this study reinforces the importance of active learning methodologies and the role of tangible learning aids in facilitating complex technical understanding.

Despite the promising results, this study is subject to several limitations. The pre-experimental one-group pretest-posttest design, while practical for classroom implementation and ethically sound in an educational setting, lacks a control group. This limits the ability to definitively attribute all observed learning gains solely to the prototype intervention, as other external factors might have contributed. Future research could employ a quasi-experimental design with a control group to enhance internal validity. Additionally, the study was conducted at a single vocational school with a specific student demographic, which may limit the generalizability of the findings to other contexts or regions. Causal inference is limited by the one group pretest–posttest design (no control), potential testing effects, and the single site. The instrument comprised 20 multiple choice items focused on C2–C4; higher order and performance-based competencies were not directly assessed, and no delayed post test was conducted to examine retention.

Future research could explore the long-term retention of knowledge and skills acquired through prototype-based learning. Investigations into the effectiveness of hybrid motorcycle prototypes across different vocational schools or technical domains, potentially using comparative designs, would also be valuable. Furthermore, qualitative studies could provide deeper insights into student and teacher perceptions of the prototype's usability and impact on teaching practices. Developing and evaluating more advanced hybrid motorcycle prototypes incorporating additional features or diagnostic capabilities could also be a fruitful area for future work.

5. Conclusion

Implementing a hybrid motorcycle prototype as learning media produced a very large improvement in students' cognitive outcomes, with mean scores rising from 58.5 to 82.67 and paired effect sizes in the large range; the class average N-Gain was 0.55 (medium), and the share of students reaching KKM ≥75 increased from 23.3% to 90.0%. These results support the value of direct, hands-on engagement for consolidating abstract concepts in hybrid powertrains and for meeting vocational competency targets aligned with the Merdeka Curriculum.

Author's declaration

Author contribution

Ramdhani: Conceptualization, Writing-original draft and Writing-review & editing, **Ridwan Adam M. Noor:** Methodology and Supervision, **Sriyono:** Investigation, **Nabiel Jabbar Fal:** Investigation, **Wahid Munawar:** Formal analysis. **Muhamad Maris Al Gifari:** Formal analysis.

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Conflict of interest

The authors declare no competing interests.

Ethical clearance

The study received approval from the school and complied with institutional ethics policies. Informed consent (and parental consent, where required) was obtained after clear explanation of aims, procedures, benefits, and potential risks. Participant identities were anonymized and data were used solely for academic purposes.

Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI statement

The grammatical structure of this article was improved by using ChatGPT and the authors have rechecked the accuracy and correctness of the generated sentences with the topic and data of this study.

Publisher's and Journal's note

Universitas Negeri Padang as the publisher, and the Editor of Jurnal Pendidikan Teknologi Kejuruan state that there is no conflict of interest towards this article publication.

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