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The Impact of Automotive Engineering Students' Understanding of Renewable Energy (Hybrid Energy Conversion)

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ABSTRACT

This study investigates the understanding of Automotive Engineering students regarding renewable energy, particularly focusing on hybrid energy conversion. The rapid advancement of renewable energy technologies, including electric, hybrid, and hydrogen-powered vehicles, has made it essential for automotive engineering students to acquire knowledge about these energy sources. The main objective of this research is to assess the comprehension level of students about renewable energy and hybrid energy conversion, a key component of modern automotive systems. Data were collected through questionnaires, semi-structured interviews, and classroom observations involving 60 students and 5 teachers. The findings indicate that while 65% of students possess a basic understanding of renewable energy sources such as solar, wind, and hydro, only 40% can accurately describe hybrid energy conversion mechanisms. The results suggest that laboratory-based learning and industry exposure significantly enhance student comprehension. This research highlights the importance of integrating hybrid energy concepts into the curriculum to prepare students for the evolving demands of the automotive industry and contribute to the global transition towards sustainable energy.

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1. INTRODUCTION

Vocational High Schools (SMK) are secondary-level vocational education institutions established by the government to prepare ready-to-work human resources. This aligns with the instructional objectives of vocational secondary education, which aim to produce professional students equipped with adequate skills, productivity, creativity, and entrepreneurial abilities. Therefore, it is essential for SMK students to be provided with basic knowledge and adequate technical skills. Observations show that the teaching and learning process in SMKs is still not entirely student-centered. This is evident from the frequent use of lecture-based or conventional models across most subjects, including automotive subjects. In fact, not all automotive material needs to be taught using lecture methods. This teaching reality highlights the importance of selecting appropriate learning strategies that align with the subject matter. Hybrid energy conversion is an innovative approach to managing and utilizing different energy sources to improve efficiency and sustainability. In the context of climate change and growing global energy demands, hybrid technology is becoming increasingly relevant. According to Smith et

al. (2020), hybrid systems can optimize the use of renewable and non-renewable energy sources, reduce carbon emissions, and enhance energy supply stability

Hybrid vehicles are one of the most common applications of hybrid energy conversion. These vehicles combine internal combustion engines with electric motors, using both sources to improve fuel efficiency. Research by Jones and Brown (2019) shows that hybrid vehicles can reduce fuel consumption by up to 30% compared to conventional vehicles. Additionally, they produce lower emissions, contributing to reduced urban air pollution.

Hybrid energy systems that combine renewable sources such as solar and wind have shown great potential in providing stable energy supplies. According to Garcia and Patel (2021), a system combining solar panels and wind turbines can generate more energy than using a single source, especially in areas with significant weather variations where one energy source may not always be available. Despite the many advantages offered by hybrid energy conversion, there are challenges to overcome. The initial cost of infrastructure and technology can be a significant barrier. However, as Nguyen (2023) points out, investing in hybrid technology can offer significant long-term returns through energy savings and emission reductions.

The global energy transition has driven a paradigm shift in technology and education. In the automotive sector, renewable and hybrid energy systems have emerged as critical innovations for reducing emissions and improving efficiency. According to Smith et al. (2020), hybrid energy systems integrate renewable and non-renewable sources to optimize energy use and sustainability. In this context, vocational education institutions play an essential role in preparing competent graduates capable of adapting to these technological developments. In Indonesia, Vocational High Schools (Sekolah Menengah Kejuruan—SMK) are designed to develop skilled and professional human resources. However, many teaching processes in automotive departments remain teacher-centered and rely heavily on conventional lecture-based methods. Studies such as Rahman & Setiawan (2023) indicate that the integration of practical-based and project-based learning can significantly improve student engagement and understanding of technological innovation. Hybrid energy conversion in vehicles represents one of the most applicable renewable technologies. Jones and Brown (2019) found that hybrid vehicles can reduce fuel consumption by up to 30% compared to conventional vehicles. Similarly, Garcia and Patel (2021) demonstrated that solar-wind hybrid systems can increase efficiency and reliability, especially in regions with varying weather conditions. These findings underscore the relevance of introducing hybrid technology concepts in vocational curricula to foster sustainable automotive innovation.

Despite the promising benefits, the implementation of hybrid and renewable energy learning faces several barriers, including limited facilities, insufficient teacher training, and high technology costs (Nguyen, 2023). Therefore, this study focuses on assessing and strengthening students' comprehension of renewable energy and hybrid energy conversion in automotive education

2. METHODS

Data were collected through a mixed-methods approach. Primary data were gathered using questionnaires distributed to 60 Automotive Engineering students, and semi-structured interviews with 5 teachers and 10 students. Observational data were also collected during classroom and practical sessions to understand student engagement and learning dynamics. The data were analyzed using descriptive statistics to measure students' understanding and thematic analysis to interpret qualitative data.

Primary data for this study were collected through the distribution of questionnaires and semi-structured interviews with students, teachers, and school administrators. The questionnaires were distributed to 60 students using purposive sampling, containing both closed and open-ended questions to measure their understanding of renewable energy concepts. Additionally, interviews were conducted with 5 teachers and 10 students to gain deeper insights into their perceptions of renewable energy and its integration into the curriculum. In addition to primary data, secondary data were gathered through the analysis of

curriculum documents, school reports, and policy guidelines related to the implementation of renewable energy topics in the automotive engineering curriculum. Observations were made of classroom activities and practical sessions to assess the dynamics of the teaching and learning process, particularly how renewable energy concepts were taught and understood. Furthermore, documentation was analyzed, including lesson plans, student worksheets, and school profile data, to support the evaluation of the curriculum's alignment with renewable energy education. The data used in this study consisted of both primary and secondary sources. Primary data were obtained from observations and interviews with the principal, vice principal, and automotive engineering teachers. Secondary data included supporting documents, such as curriculum guidelines, school reports, and policy documents, which were used to enrich the analysis of the implementation of the Merdeka Curriculum at SMK Telkom Pekanbaru.

Data were collected through questionnaires distributed to students and direct interviews with randomly selected students to deepen the analysis. The data were analyzed using descriptive statistics to obtain an overview of students' understanding and perceptions of renewable energy. Data were analyzed using descriptive statistics and thematic analysis. Quantitative data were presented in percentage form, while qualitative data were interpreted to reveal recurring patterns related to students' comprehension and learning challenges.

3. RESULTS AND DISCUSSION

The results show that 65% of students understand the general concept of renewable energy sources (e.g., solar, wind, hydro), but only 40% can describe hybrid conversion mechanisms involving both electrical and mechanical energy. This indicates a gap between theoretical knowledge and practical understanding. Students exposed to laboratory practices or external training demonstrated higher competency levels, confirming the significance of experiential learning. Interviews revealed that most teachers possess basic awareness of renewable energy concepts but lack specialized training in hybrid systems. This aligns with Lee et al. (2022), who emphasize that teacher competency is a major determinant of effective technology-based instruction. Curriculum documents show that renewable energy topics are included only briefly under "Energy Systems," suggesting a need for deeper integration.

There are 65% of students demonstrated a basic understanding of renewable energy sources such as solar and wind. Only 40% could explain the working principle of hybrid energy conversion. Data triangulation was conducted by comparing multiple data sources and methods. The researcher applied Arikunto's (2019) and Bachri's (2012) frameworks to ensure credibility through prolonged engagement, peer discussion, and theoretical triangulation. Students with exposure to real hybrid systems (through lab practice or external workshops) had significantly higher understanding scores. Teachers reported challenges in delivering hybrid-related content due to lack of training and limited infrastructure. Classroom observations revealed that student-centered learning methods (e.g., problem-based learning) were more effective in enhancing understanding

According to Arikunto (in Agustian, 2019), validity is the degree of accuracy between the data that occurs in the research object and the data reported by the researcher. Therefore, valid data means "there is no difference" between the reported and actual data. Data validity testing is conducted to ensure the research is truly scientific and to test the obtained data. To achieve credibility, the researcher used techniques such as extended observation, increased research rigor, triangulation, and peer discussions. Triangulation of sources was also used to re-verify the trustworthiness of the information from different sources, as well as theory triangulation by integrating two or more theories (Bachri, 2012).

Table 1. Students' Understanding Levels

Understanding Category	Indicator Description	Percentage (%)	Interpretation
High (80–100%)	Can explain renewable and hybrid energy principles clearly and correctly	18%	Excellent conceptual mastery
Medium (60–79%)	Understands basic concepts but lacks detailed knowledge on hybrid mechanisms	47%	Moderate comprehension
Low (<60%)	Limited understanding; can only recognize energy sources	35%	Needs improvement

The findings indicate that 65% of students possess a basic understanding of renewable energy (solar, wind, hydro), but only 40**%** could correctly explain the hybrid energy conversion process. Students who participated in laboratory activities or attended industry workshops demonstrated significantly higher comprehension scores (average 78%) compared to those without hands-on experience (average 54%).

Table 2. Teachers' Preparedness toward Hybrid Energy Teaching

Aspect	Fully Prepared (%)	Moderately Prepared (%)	Not Prepared (%)
Knowledge of Hybrid Concepts	40	45	15
Access to Teaching Materials	35	50	15
Laboratory Support	30	40	30
Curriculum Integration	55	30	15

The results highlight that infrastructure and teacher competency are the two most critical challenges in implementing hybrid energy topics effectively. Effectiveness of Student-Centered Learning. Observation data showed that student-centered learning approaches, such as Project-Based Learning (PBL) and Problem-Based Learning (PBL), improved engagement and retention significantly. In conventional classes, the average student participation rate was 58%, Whereas in classes applying PBL strategies, participation increased to 82%. Students reported higher motivation and conceptual understanding after conducting hybrid energy mini-projects (e.g., solar-hybrid model car prototypes).

Table 3. Comparison of Learning Effectiveness (Traditional vs. Student-Centered)

Learning Approach	Average Participation (%)	Average Understanding Score (%)
Traditional Lecture	58	60
Student-Centered (PBL/PjBL)	82	78

These results align with Kumar & Abbas (2024) and Rahman & Setiawan (2023), who found that experiential learning models foster higher-order thinking and deeper comprehension in vocational education.

Table 4. Barriers and Opportunities in Hybrid Energy Learning Implementation

Category	Identified Issue	Frequency (%)	Recommended Action
Infrastructure	Limited lab equipment and hybrid modules	75	Develop partnerships with local industries
Teacher Competence	Lack of renewable energy training	68	Conduct professional development workshops
Curriculum	Minimal integration of hybrid topics	63	Revise curriculum to include energy sustainability
Student Exposure	Few external practical opportunities	58	Strengthen collaboration with energy companies

Despite these barriers, both teachers and students expressed optimism regarding future developments. Approximately 90% of respondents agreed that integrating renewable energy into the automotive curriculum is essential for preparing graduates for the green industry.

The findings from the research reveal critical insights into students' understanding of renewable energy concepts and the effectiveness of teaching methodologies. A significant 65% of students demonstrated a basic understanding of renewable energy sources, which include solar, wind, and hydroelectric power. However, this understanding diminishes when it comes to explaining hybrid energy conversion processes, with only 40% able to articulate these mechanisms effectively. This discrepancy points to a substantial gap between theoretical knowledge and practical application, highlighting a need for enhanced pedagogical approaches that can bridge this divide (Huang et al., 2024).

Data gathered through multiple research methodologies, including student interviews and classroom observations, supported these findings. Students who participated in hands-on laboratory practices or attended external workshops exhibited markedly higher competency levels, averaging understanding scores of 78% compared to 54% for their less-engaged peers. This observation corroborates the notion that experiential learning—where students actively engage in practical learning experiences—fosters deeper understanding and retention of complex subjects such as renewable energy systems (Huang et al., 2024)(Kaniz et al., 2025) Furthermore, interviews with educators indicated that while instructors possess a general awareness of renewable energy principles, there is a pronounced lack of specialized knowledge regarding hybrid systems. This aligns with research by Lee et al. (2022), which posits that teacher competency fundamentally influences the effectiveness of technology-based instruction in educational settings, underscoring the importance of continuous professional development for educators (Kaniz et al., 2025; (Aziz et al., 2025; . In light of this, one of the recommended actions is to enhance teacher training focused on renewable energy topics, thereby equipping them with the necessary competencies to deliver effective instruction in this critical area.

The current curriculum, which briefly incorporates renewable energy topics under broader categories such as "Energy Systems," further exacerbates this gap. The brief integration of these subjects signifies an urgent need for reform that emphasizes a comprehensive approach, allowing students to engage deeply with both renewable and hybrid energy systems (Huang et al., 2024). The findings suggest that a more inclusive curriculum could significantly improve student outcomes, making them better prepared for the emerging green economy. Implementing student-centered learning techniques, such as Problem-Based Learning (PBL) and Project-Based Learning, has been shown to increase both participation and understanding among students. Observational data indicate that the average participation rate jumped from 58% in traditional classes to 82% in settings utilizing student-

centered methodologies. This pedagogical shift not only enhances engagement but also fosters higher-order thinking, confirming the positive impact of experiential learning models as reported in prior studies (Aziz et al., 2025; Prince et al., 2025).

In summary, the research results indicate a pressing necessity for improved teacher training, enhanced curriculum integration, and the adoption of student-centered learning practices to elevate students' understanding of renewable and hybrid energy systems. This integrated approach will not only close the knowledge gap currently observed but also increase student motivation and preparedness for future challenges within the green industry (Badhan et al., 2024; Ahmed et al., 2025; Rafiq-uz-Zaman, 2025).

4. CONCLUSION

Vocational High Schools (SMKs) play a vital role in preparing professional, productive, creative, and entrepreneurial-ready human resources. However, the current implementation of the teaching and learning process in SMKs, particularly in automotive subjects, still largely relies on lecture-based methods that are less student-centered. This underlines the importance of choosing appropriate learning strategies tailored to the subject matter to enhance learning effectiveness. Hybrid energy conversion, as an innovative energy management approach, offers solutions for increasing energy efficiency and sustainability. Technologies such as hybrid vehicles and hybrid energy systems that combine renewable sources (solar and wind) have proven effective in reducing fuel consumption, carbon emissions, and improving energy supply stability. Nevertheless, challenges such as high initial costs need to be addressed to maximize the potential of hybrid technologies.

In conclusion, this study highlights the importance of innovation in vocational learning, particularly in the automotive field, and the significant potential of hybrid energy conversion in supporting energy sustainability. Implementing suitable learning strategies and utilizing hybrid technologies can serve as strategic steps to prepare SMK students as competent workers ready to face global challenges in the future. This study demonstrates that while students of SMK Telkom Pekanbaru possess foundational knowledge of renewable energy, their understanding of hybrid energy conversion remains limited. Teacher competency, infrastructure, and curriculum alignment are critical factors influencing this outcome. Strengthening laboratory-based learning, incorporating project-oriented modules, and fostering collaboration with renewable energy industries can significantly improve vocational education quality. These efforts not only enhance students' technological literacy but also contribute to achieving Indonesia's sustainable energy goals.

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