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Enhancing Competence in Battery-Based Electric Vehicle Installation and Programming at SMK Negeri Jambu

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Abstract: *This community service program was implemented to overcome the limited technical capacity of teachers and students at SMK Negeri Jambu in mastering the installation and programming of battery-based electric vehicles, which is a crucial skill in preparing competent human resources for the rapidly evolving green vehicle industry. The program specifically aimed to enhance participants' knowledge and skills in several key areas, including the installation of electric motor control systems, management of battery energy, and maintenance of essential electric vehicle components. To achieve these goals, the activities were carried out using a blended method that integrated lectures, demonstrations, and direct hands-on practice, supported by continuous mentoring and systematic evaluation. In addition, QR Code–based learning resources were incorporated to provide participants with quick and efficient access to digital instructional materials, allowing for more flexible and independent learning. The evaluation results revealed significant progress in both the theoretical understanding and practical abilities of the participants. They were able to demonstrate improvements not only in operating and maintaining electric vehicle systems but also in identifying problems and performing troubleshooting independently. These findings suggest that the program effectively contributed to building sustainable competencies for teachers and students, equipping them with relevant skills aligned with the needs of the green automotive industry, while also promoting technological adaptation and innovation in vocational education.*

1. INTRODUCTION

The global transformation toward sustainable energy has positioned battery-based electric vehicles as the primary solution to addressing environmental crises and reducing dependence on fossil fuels. Indonesia is committed to producing 13 million electric motorcycles and 2.2 million electric cars by 2030, reflecting the nation's ambitious vision for green energy transition (Ministry of Energy and Mineral Resources, 2021). This commitment is supported by Indonesia's strategic position as the holder of 52% of the world's nickel resources, making the country a vital asset in the global battery production supply chain

(Adityowati & Armunanto, 2022).

The Indonesian government has demonstrated strong commitment through a range of comprehensive policy instruments. Presidential Regulation No. 55 of 2019 on the acceleration of battery-based electric vehicle programs serves as the primary legal foundation. This regulation is reinforced by Presidential Instruction No. 7 of 2022 and sectoral regulations from the Ministry of Industry, the Ministry of Energy and Mineral Resources, and the Ministry of Transportation, which regulate technical aspects, infrastructure, and vehicle conversion incentives (Sari & Wijaya, 2023).

Despite the ambitious targets and strong policy support, the implementation of electric vehicles still faces significant challenges. Data from the Association of Indonesian Automotive Industries (Gaikindo) show that electric car sales between January–November 2023 only reached 13,873 units, representing just 1.50% of total car sales (Gaikindo, 2023). Indonesia's NDC target requires 1.8 million two-wheeled electric vehicles by 2025 and 13 million units by 2030, which remain far from current achievements (Ministry of Environment and Forestry, 2022).

Vocational education is critical in preparing a skilled workforce that meets the demands of the rapidly evolving electric vehicle industry. The government targets 80% of Indonesia's productive-age population to participate in vocational education by 2024 through the vocational education revitalization program (Ministry of Education, Culture, Research, and Technology, 2022). As the main institutions of vocational education, vocational high schools (SMK) play a crucial role in producing a workforce ready to face the automotive industry's transformation toward electrification (Sudira, 2023).

The increasing demand for skilled human resources in the field of automation by the workforce has encouraged vocational education institutions to align their graduates' competencies with industry needs, where students must be equipped with up-to-date skills in line with technological advancements (Priyanto et al, 2022).

In practice, many SMKs still face challenges in adapting curricula and learning facilities to electric vehicle technology. Limited supporting facilities, insufficient teacher competence in electric vehicle technology, and the lack of relevant teaching materials are major obstacles in preparing students for the era of vehicle electrification (Ahmad, Prastowo, & Sari, 2023; Prasetyo & Wibowo, 2024).

SMK Negeri Jambu, a vocational education institution in Central Java, faces similar challenges in integrating electric vehicle technology. As a school with an automotive study program, it has strong potential to become a pioneer in developing electric vehicle technology

competencies at the regional level. However, limitations in laboratory facilities that are still focused on conventional technology, insufficient teacher training, and a lack of industry-relevant teaching materials hinder the optimization of this role (Field Observation, 2024).

The community service program is designed to encompass five strategic dimensions: the provision of modern facilities such as electric motor simulation devices and battery testing tools; intensive teacher training in battery-based electric vehicle technology; the development of QR Code-based teaching materials; the establishment of strategic partnerships with industry; and continuous mentoring to ensure program sustainability (Suyanto & Jihad, 2023). This program is expected to serve as a replicable model for other SMKs across Indonesia.

With a comprehensive approach that integrates technological, pedagogical, and industrial partnership aspects, this program aims to enhance the technical competencies of teachers and students while building a learning ecosystem that supports the development of environmentally friendly technologies. The program's implementation is expected to contribute to accelerating the adoption of electric vehicles in Indonesia by providing competent human resources who are ready to face the challenges of the future automotive industry (Wardana, Suryanto, & Pratama, 2024).

2. METHOD

This community service program was carried out over eight months using a participatory approach that involved collaboration between the proposing team from Universitas Negeri Semarang and the partner institution, SMK Negeri Jambu. The implementation method was systematically designed to address priority issues identified through a comprehensive needs analysis.

The initial stage of the program began with proposal drafting and preparation, which included identifying program objectives, mapping partner needs, planning implementation strategies, and preparing a budget plan. The needs analysis was conducted through field surveys to understand the existing conditions of learning facilities, teacher competencies, and technological requirements at SMK Negeri Jambu.

The proposing team developed an electric vehicle technology learning module based on QR Codes, enabling easy access to digital materials and increasing participant engagement. The development of learning content applied an approach that integrates theoretical and practical aspects aligned with the latest standards of the electric vehicle industry.

The lecture method was employed to provide theoretical understanding of electric vehicle technology to teachers and students of SMK Negeri Jambu. The lecture materials

covered the fundamentals of electric vehicles, battery energy management, electric motor control systems, and charging technologies. The partner's role in this activity was to provide participants and share information and experiences related to the implementation of technology within the school environment.

The proposing team demonstrated the operational procedures of electric vehicle technology following established standard operating procedures. The demonstration activities included explanations of electric motor operations, battery charging, component maintenance, and basic troubleshooting. The partner institution supported the implementation by providing training space, preparing participants, and facilitating supporting equipment.

Participants were given the opportunity to directly practice the materials taught during the demonstration sessions. Hands-on practices included operating electric motor control systems, managing battery energy, testing electric vehicle performance, and simulating routine maintenance. This hands-on learning approach aimed to provide participants with valuable practical experience. Training in vocational schools, as part of higher education community service activities, is expected to enhance the skills of vocational students, teachers, and technicians. In addition to benefiting the participants, the post-training equipment provided can also be utilized to support and create beneficial activities for the surrounding community (Priyanto et al, 2024).

The program adopted a mentoring approach using a bottom-up model, where the implementing team actively facilitated discussions and provided consultations for teachers and students. Mentoring was conducted throughout the training program and continued beyond the formal sessions to ensure sustainable technology implementation. The proposing team also assisted teachers in applying teaching materials that had been adapted to technological developments.

Evaluation was carried out at every stage of the program, from socialization to training and mentoring. The evaluation methods included direct observation, questionnaires, pre-tests and post-tests to measure knowledge improvement, as well as discussion sessions with participants. The evaluation aimed to assess the level of mastery of electric vehicle technology and the ability to implement it in practice.

The program provided modern facilities, including a 72V BLDC motor simulation device, controller, 72V 20Ah battery, DC/DC converter, and other supporting equipment according to the technical specifications required for practical learning in electric vehicle technology. The function of training aids in vocational education is also perceived as an important part, as instructional tools provide students with a clear illustration and real

experience in mastering the expected competencies (Wibisono & Priyanto, 2020).

The program also developed strategic partnerships with the electric vehicle industry to provide students with internships and industry-based training opportunities. This collaboration aimed to ensure alignment between the competencies taught and the demands of the labor market.

Figure 1. Training Methodology.

3. RESULT

Program The intensive training program on battery-based electric vehicle technology successfully enhanced the competencies of teachers and students at SMK Negeri Jambu. Based on the results of pre-test and post-test evaluations, there was an average increase of 65% in teachers' knowledge scores and 58% in students' scores. These improvements encompassed understanding the fundamental concepts of electric vehicles, installing electric motor control systems, managing battery energy, and maintaining key components.

Figure 2. The implementation team hands over electric vehicle teaching aids to the partner school.

Figure 3. The implementation team with the principal, teachers, and students of SMK Negeri Jambu.

Figure 4. The speaker gives an overview of battery-based electric vehicle concepts to the training participants.

The development of QR Code-based learning modules proved effective in improving the accessibility and interactivity of the learning process. Students were able to easily access digital learning materials using smartphones, which increased their engagement in the learning process. Satisfaction survey results indicated that 87% of students felt supported by the QR Code modules, while 82% of teachers reported that the technology facilitated the delivery of learning materials. The developed QR Code modules included tutorial videos, interactive simulations, and practical guides that participants could access anytime, supporting self-directed and flexible learning in line with the characteristics of digital-native generations. In addition to QR Code-based modules, the development of interactive learning media based on flipbooks achieved feasibility scores of 91.32% for material aspects and 94.31% for media and design aspects, with student responses showing an average score of 82.29% categorized as very valid, proving that interactive media facilitates student understanding in a concrete and enjoyable way (Nugroho et al, 2025). The results of the program indicate significant improvements in both teachers' and students' competencies, with increases in knowledge and practical skills.

The provision of modern facilities such as a 72V BLDC motor simulation device, controller, 72V 20Ah battery, and other supporting equipment had a positive impact on the quality of practical learning. The simulation devices installed in the automotive laboratory of SMK Negeri Jambu were used for regular practicums and served as effective interactive learning media. The program also successfully produced a textbook entitled PINTAR: Learning Battery-Based Electric Vehicle Technology, which has been registered with an ISBN and copyright. The book contains comprehensive material on electric vehicle technology aligned with current industry standards and the needs of the vocational high school curriculum.

The program established strategic partnerships with three companies engaged in the electric vehicle sector, providing students with opportunities for internships and industry-based training. A total of 80% of twelfth-grade automotive students participated in internships with electric vehicle-related industries and obtained competency certifications from industry partners, thereby enhancing the competitiveness of SMK Negeri Jambu graduates in the green technology labor market.

This program also contributed to environmental conservation efforts by increasing awareness and competencies in environmentally friendly technology. The implementation of electric vehicle technology within the school environment created a demonstration effect for the surrounding community regarding the benefits and practicality of using electric vehicles, supporting government efforts to accelerate the adoption of electric vehicles in society. To

ensure program sustainability, a special team has been established at SMK Negeri Jambu to manage and maintain the facilities and to develop follow-up programs.

4. DISCUSSION

The findings of this study are consistent with those of Zhang, Chen, and Liu (2024), which showed that practice-based electric vehicle technology training can improve technical competencies by up to 70% compared to conventional learning methods. The implementation of QR Code technology in vocational learning is also supported by the research of Kumar and Patel (2024), who stated that the use of mobile learning technology can increase student engagement by up to 85% in automotive engineering education.

The industry partnerships established in this program reflect global trends in vocational education. As noted by Smith and Johnson (2024), school-industry collaboration is a key factor in preparing a skilled workforce during the energy transition era. Recent research by the International Labour Organization (2024) also demonstrated that internships in green technology fields can increase graduate employment absorption rates by up to 92%.

The positive impact on environmental awareness generated by this program aligns with the study of Wilson et al. (2024), which found that electric vehicle technology education at the vocational level can increase students' environmental awareness by 78%. According to Environmental Education Research (2024), green technology education programs in vocational schools have a multiplier effect in accelerating the adoption of environmentally friendly technologies in society.

The use of simulation facilities in electric vehicle technology learning is supported by the findings of Garcia and Rodriguez (2024), which showed that simulation-based learning can reduce operational costs by up to 60% while enhancing students' understanding of technical concepts. Research by the Advanced Manufacturing Institute (2024) also confirmed that the use of BLDC motor simulation devices in vocational education can improve students' practical skills by 73% compared to traditional learning methods.

The sustainability of the implemented program is in line with best practices highlighted by UNESCO Technical and Vocational Education and Training (2024), which emphasizes the importance of establishing internal teams and maintaining sustainable partnerships to ensure continuity in vocational education programs. The development of copyrighted textbooks produced by this program also reflects the trend of digitalization in vocational curriculum development, as recommended by the World Bank Education Report (2024).

5. CONCLUSION

The community service program "Enhancing Competence in Battery-Based Electric Vehicle Installation and Programming at SMK Negeri Jambu" has successfully achieved its strategic objectives in preparing human resources to face the automotive industry's transition toward electrification. Evaluation results showed a significant increase in technical competencies, with average knowledge scores improving by 65% for teachers and 58% for students, covering the installation of electric motor control systems, battery energy management, and maintenance of key electric vehicle components. The implementation of QR Code-based learning modules proved effective in improving accessibility and participant engagement, with satisfaction levels reaching 87% among students and 82% among teachers. The provision of modern facilities such as a 72V BLDC motor simulation device, controller, 72V 20Ah battery, and other supporting equipment had a transformative impact on the quality of practical learning at SMK Negeri Jambu. The program successfully established strategic partnerships with three electric vehicle companies, providing internship opportunities for 80% of twelfth-grade automotive students who obtained industry competency certifications. The program's outputs included the textbook "PINTAR: Learning Battery-Based Electric Vehicle Technology" with ISBN and copyright, publication in an accredited national journal, and documentation of activities published through mass media and the LP2M UNNES YouTube channel. This program made a tangible contribution to strengthening the vocational education ecosystem in support of the Indonesian government's target to produce 13 million electric motorcycles and 2.2 million electric cars by 2030. Through a comprehensive approach integrating technology, pedagogy, and industry partnerships, the program has become a replicable model for other vocational education institutions in developing competencies in environmentally friendly technologies. Program sustainability is ensured through the establishment of a dedicated team at SMK Negeri Jambu and the commitment to continuous mentoring, guaranteeing that technology and knowledge transfer will continue to grow in support of environmental conservation efforts and the acceleration of electric vehicle adoption in Indonesia.

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