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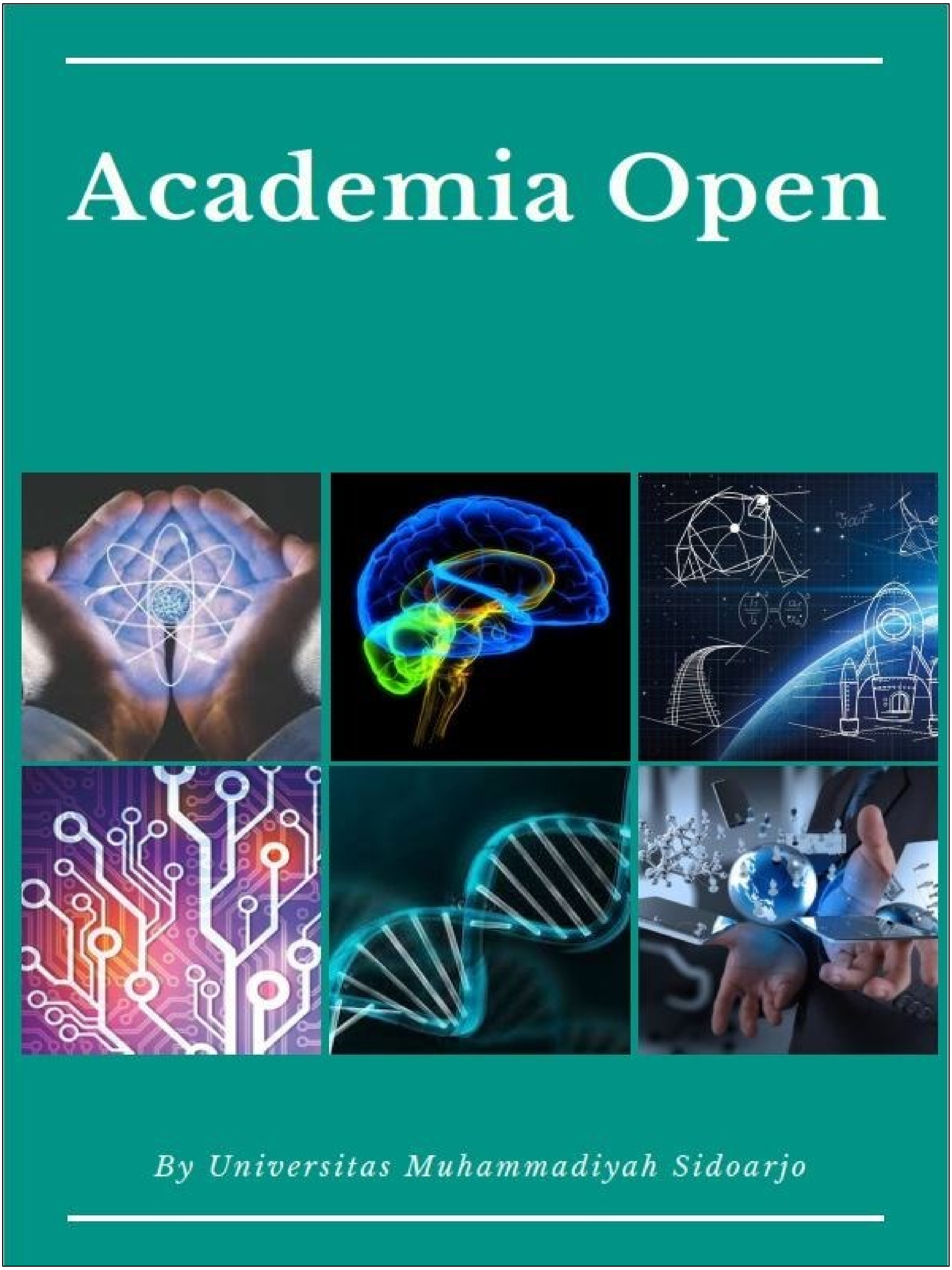

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Education on the Application of Electrical Technology Through Creative Learning Projects: Pendidikan tentang Penerapan Teknologi Listrik Melalui Proyek Pembelajaran Kreatif

Pendidikan tentang Penerapan Teknologi Listrik Melalui Proyek Pembelajaran Kreatif

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Abstract

General Background: The rapid advancement of technology demands innovative approaches in education to equip students with essential STEM competencies. **Specific Background:** In Indonesia, high school learning of electrical engineering is still dominated by theoretical instruction with limited opportunities for hands-on practice, resulting in low engagement and inadequate technical skill development. **Knowledge Gap:** Few initiatives integrate real-world electrical engineering applications into secondary education through creative, project-based learning. **Aim:** This study reports on the implementation and evaluation of a creative learning outreach program conducted by Universitas Pembangunan Nasional Veteran Jakarta at SMA Negeri 66 Jakarta, designed to enhance students' understanding of electrical technology. **Results:** The program engaged 72 students through three interactive modules: portable solar power storage, a mechatronic sumo robot, and IoT-based drowsiness detection glasses. Evaluation results showed a 28% increase in interest toward STEM careers, a 35% improvement in conceptual understanding, and positive perceptions of program delivery. **Novelty:** Unlike conventional lectures, this initiative combined project-based learning with real-world prototypes, directly linking theory with application and fostering creativity, collaboration, and problem-solving. **Implications:** These findings highlight the value of integrating interactive, technology-driven projects into secondary education, offering a scalable model for strengthening STEM literacy and preparing future engineers.

Highlight :

- Hands-on modules (solar power, sumo robot, IoT glasses) increased student engagement.
- Survey showed 28% higher STEM interest and 35% better understanding of technology.
- Program effectively connected theory with real-world applications in electrical engineering.

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Keywords : Education, Creative Learning Project, Electrical Technology, Project-Based Learning, STEM

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Introduction

The accelerating pace of technological advancement has transformed nearly all sectors of society, particularly education, where integrating electrical engineering and digital innovation into secondary schools has become essential to prepare students for future challenges [1], [2], [3]. High school engagement with fundamental electrical and electronic concepts offers critical groundwork, equipping learners with both theoretical knowledge and practical abilities relevant to modern innovation demands [4], [5].

However, multiple studies in Indonesia have shown that practical activities in electrical engineering at the high school level remain very limited. Instruction is still heavily dominated by classroom theory, with minimal laboratory facilities and infrequent opportunities for hands-on practice [6], [7]. As a result, students often lack exposure to the real-world application of electrical and electronics concepts, which hinders the optimal development of technical skills, problem-solving abilities, and creativity. These findings highlight the urgency of implementing creative, project-based learning programs that bridge the gap between theory and practice through the integration of modern technologies.

One effective approach is project-based learning (PBL), which bridges theory and practice by involving students in meaningful tasks such as building solar-powered systems, robotic devices, and smart IoT applications. Studies demonstrate that PBL enhances computational thinking, problem-solving, and team collaboration in STEM education [8], [9], [10]. Additionally, integrating flipped classrooms alongside PBL further improves student motivation and algorithmic thinking skills [11], [12].

A modern extension of PBL is using IoT-enabled laboratory tools like EduSolar systems for solar energy monitoring, which promote hands-on data analysis and deepen understanding of renewable energy technology [13], [14]. Wearable devices such as smart glasses with drowsiness detection have shown potential to improve student engagement and safety awareness in educational settings [15]. Moreover, research supports the use of smart education systems combining IoT, AI, and 5G for enhancing interactive learning and real-time feedback [16].

In SMA Negeri 66 Jakarta, the Electrical Engineering Department of UPN Veteran Jakarta implemented a creative learning project featuring three main modules such as Portable solar power storage, Mechatronic sumo robots and IoT-enabled drowsiness detection glasses. These modules contextualize essential electrical engineering principles such as circuit design, energy conversion, embedded control, and wireless communication making learning engaging and relevant [17]. The program aims to Foster foundational literacy in electricity and electronics, Encourage creativity, innovation, and teamwork, Cultivate essential technical and soft skills, Enhance awareness of future careers in electrical engineering. These objectives align with studies demonstrating that early exposure to engineering fosters student readiness for higher education and contributes to workforce development [18].

This paper explores the design, implementation, and evaluation of the creative learning initiative at SMA Negeri 66 Jakarta. It examines the program's effects on students' technical competencies, attitudes toward STEM, and readiness for advanced studies. Outcomes from surveys, skill assessments, and feedback sessions provide insight into the project's effectiveness as a scalable model for STEM education reform in Indonesia.

Implementation Method

A. Timing of Implementation

The creative learning project was implemented as part of a structured community service activity on September 18, 2024, at SMA Negeri 66 Jakarta. This program was designed to align with the objectives of engineering outreach in secondary education and to introduce practical applications of electrical engineering technologies through interactive and project-based demonstrations.

B. Stages of Implementation

This initiative was carried out by the academic community of the Department of Electrical Engineering at Universitas Pembangunan Nasional Veteran Jakarta. A total of 72 students from the 12th grade of SMA Negeri 66 Jakarta participated in the program. The implementation stages are outlined in Figure 1 and described in detail below.

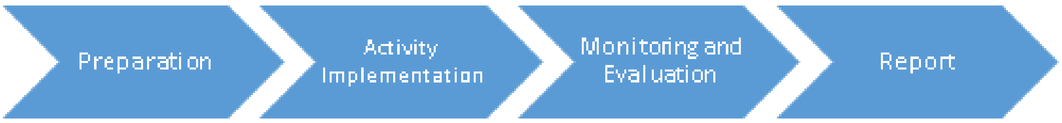

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Figure 1. Stages of the Creative Learning Project

The explanation of each stage of the service activity based on the diagram above is as follows:

1. Preparation

The preliminary stage involved conducting field observations at SMA Negeri 66 Jakarta to assess the school's infrastructure and student readiness. Interviews were conducted with teachers and students to tailor the project content and identify the tools and resources needed. These preparatory steps are critical in community-based learning projects to ensure contextual relevance and optimal student engagement.

2. Activity Implementation

The activity was opened with speeches from school representatives and the UPN Veteran Jakarta organizing committee. The core content delivery included lectures, discussions, and hands-on demonstrations of engineering projects. Students were actively involved through Q&A sessions and encouraged to participate in practical trials. To maintain engagement, an ice-breaking segment was included—an approach shown to help maintain focus and promote collaborative learning [19].

3. Monitoring and Evaluation

This phase involved systematic observation and assessment of the learning process. Student comprehension was measured through oral questioning and post-activity questionnaires. This phase involved systematic observation and assessment of the learning process. Student comprehension was measured through oral questioning and post-activity questionnaires. The questionnaire instrument was designed with clear indicators, including (1) students' interest in science and engineering, (2) understanding of technological concepts, and (3) perceived relevance of the activities to their academic and career aspirations. Each indicator was rated using a Likert scale, ranging from "good" to "very good."

For data analysis, responses were processed by calculating percentages to summarize distribution patterns, supported by simple descriptive statistics such as mean and standard deviation to identify overall trends. This quantitative analysis was complemented by qualitative observations taken during the activity. The combination of these techniques strengthened the validity of the findings and ensured that the results presented in the subsequent charts accurately reflected participants' learning experiences and engagement levels.

4. Report

The final phase involved compiling a comprehensive report that documented all aspects of the program implementation and results. This step also served as a basis for reflection and improvement in future iterations of similar activities.

C. Project Presentation

3.1 Implementation of Renewable Energy through Technological Innovation of Solar Panels Utilized as Portable Power Storage

The portable power storage module introduced students to sustainable energy technologies. Conventional power banks require charging via grid electricity or gasoline generators. As an environmentally friendly alternative, solar panels were presented as a clean and renewable source of energy. These panels convert solar radiation into electricity through photovoltaic cells typically made from semiconductors like silicon. When exposed to sunlight, the semiconductor material generates free electrons, creating an electric current [20]. A prototype device was displayed as shown in Figure 2, aligning with current trends in integrating renewable energy into education [21].

Figure 2. Appearance of The Solar Panel Device

3.2 Mechatronic Robot Sumo

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The sumo robot module exposed students to robotics and sensor systems. Designed for competitive performance, the robot detects its opponent using infrared sensors and attempts to push it outside the boundary. It features a white-line detection system to avoid leaving the arena. The robot's logic and movement are controlled by a microcontroller, while motion is powered by DC motors. This learning unit demonstrates fundamental mechatronics principles—sensor integration, control algorithms, and embedded systems—which are central to modern robotics education [22], [23]. The appearance of the robot can be seen in Figure 3.

Figure 3. Appearance of the Sumo Robot

3.3 Drowsiness Detection Glasses Based on the Internet of Things

This prototype demonstrated how IoT technology can be used to enhance safety. The system includes a NodeMCU microcontroller, infrared sensors mounted on eyeglass frames, and a buzzer for alert signaling. When a user's eyes remain closed for a period indicating drowsiness, the system triggers both an LED and a buzzer to alert them. This type of application has been extensively explored in transportation safety and demonstrates a practical use of IoT in real-time monitoring systems [24]. Figure 4 illustrates the glasses used in the demonstration.

Figure 4. Appearance of the Drowsiness Detection Glasses Based on the Internet of Things

Result and Discussion

The Creative Learning Project was successfully attended by 72 students from the 12th grade of SMA Negeri 66 Jakarta. The event officially began with an opening segment led by a master of ceremonies (MC), followed by a sequence of formal activities. These included the singing of the Indonesian national anthem "Indonesia Raya," a prayer recital, an opening speech delivered by the project coordinator, and welcoming remarks from representatives of the host school as shown figure 5.

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Figure 5. Opening of The Event

A. Project Implementation and Student Engagement

The implementation of the Creative Learning Project adopted a collaborative learning approach, fostering direct interaction between the teaching team and the students. The team, comprised of seven members from the Department of Electrical Engineering at Universitas Pembangunan Nasional Veteran Jakarta, played an active role in mentoring students throughout the project. Their guidance focused on building students' practical competencies, particularly in assembling electronic components such as microcontrollers, sensors, and supporting electrical modules into functional prototypes.

In addition to hands-on practice, students received theoretical explanations covering topics such as solar panel systems, mechatronics, Internet of Things (IoT), and career prospects in electrical engineering. The session also included an introduction to the Electrical Engineering undergraduate program at UPN Veteran Jakarta to spark student interest in pursuing higher education in the field which is illustrated in Figure 6.

Figure 6. Material Presentation

The material presentation segment was met with strong student attentiveness. Enthusiasm significantly increased during the project demonstration phase, where students engaged with three main prototype projects such as Portable Solar Power Storage, Sumo Robot, and Drowsiness Detection Smart Glasses.

Students demonstrated genuine curiosity and excitement, especially during the sumo robot demonstration. Several students actively participated by stepping forward to interact with the devices. Their involvement extended beyond observation; they asked insightful questions regarding system operation, involved components, and real-world application scenarios. These interactions indicate a positive cognitive and emotional response, showcasing the effectiveness of project-based learning in increasing student engagement and comprehension of abstract technical concepts as shown in Figure 7.

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Figure 7. Project Demonstration

B. Closing Ceremony and Evaluation

As the event concluded, the organizing committee presented souvenirs as tokens of appreciation to the school community. A group photo session and documentation were conducted to mark the successful implementation of the activity as shown in Figure 8.

Figure 8. Documentation

To evaluate the impact of the project on student learning, a questionnaire survey was distributed to the participants. The questionnaire consisted of seven key indicators aimed at measuring student understanding and awareness of electrical engineering principles, as well as their perception of related career opportunities. Based on the analysis of the responses, it was found that the students experienced a significant increase in interest and knowledge after the project. The results are presented in the graph below as shown in Figure 9:

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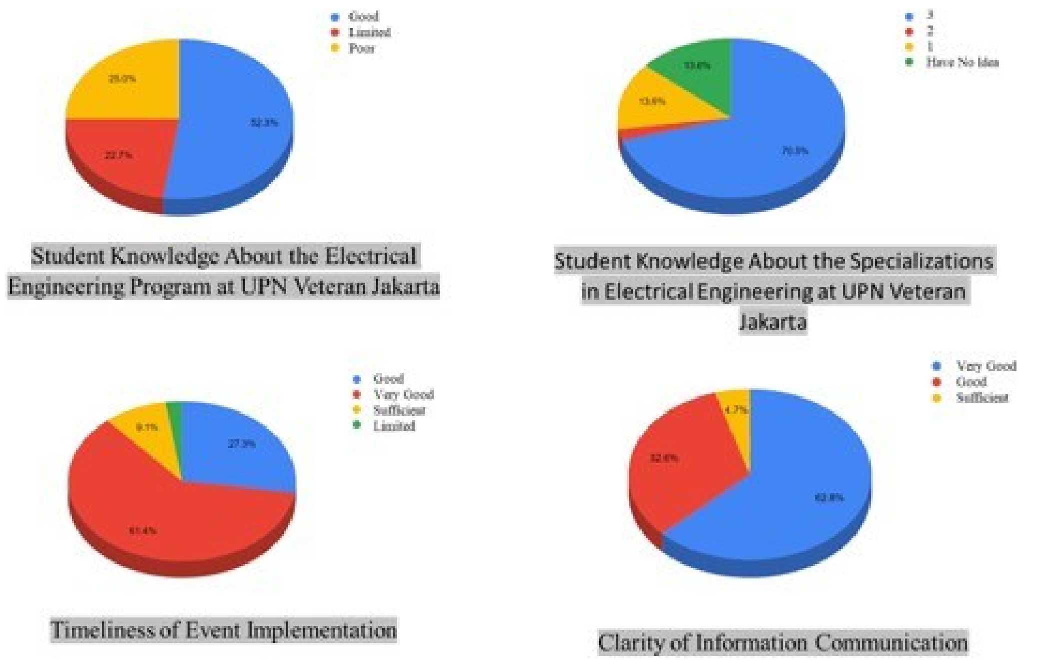

Figure 9.

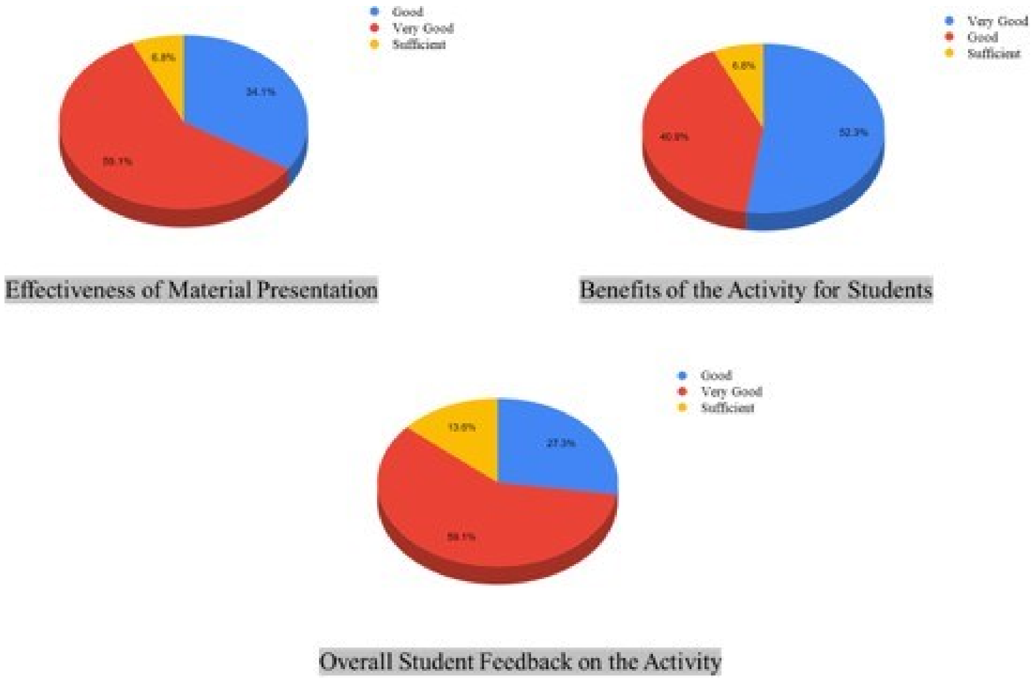

Figure 10. Questionnaire Data Results Graph

These findings affirm that creative and hands-on approaches in engineering education not only enhance conceptual understanding but also boost student motivation and interest in STEM careers. The integration of real-world technology, such as IoT systems and mechatronics, into the learning experience plays a critical role in bridging the gap between theoretical knowledge and practical application.

The success of the Creative Learning Project not only lies in the smooth execution of its planned agenda but also in the positive learning outcomes it produced. From a pedagogical standpoint, the integration of real-time demonstrations with

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theoretical content created a learning environment that was both interactive and contextual. Unlike conventional lecture-based sessions, this approach offered students the opportunity to directly engage with applied technologies, thereby enhancing retention and deepening their understanding of complex engineering principles.

The enthusiasm displayed by students during the Sumo Robot activity, for instance, highlights the effectiveness of mechatronics as a tool to teach embedded systems and control logic. As they observed and experimented with the robot's behavior in reaction to its sensors and actuators, students could draw meaningful connections between electrical signals, motor control, and decision-making algorithms. This method of experiential learning is aligned with current best practices in STEM education, which emphasize student-centered and inquiry-based models as outlined in recent studies.

Equally impactful was the IoT-based drowsiness detection system, which introduced students to emerging technologies commonly used in industry. The smart glasses served as a bridge between theoretical knowledge of sensors and practical applications in safety, transportation, and health monitoring. Students were able to grasp the function of key components such as infrared sensors, microcontrollers (e.g., NodeMCU ESP8266), and data feedback systems. For many participants, this prototype represented their first exposure to the Internet of Things, helping them appreciate how data-driven systems can address real-world problems, which is crucial for digital literacy in the 21st century.

The solar panel project, on the other hand, underscored the importance of renewable energy and sustainability. Students learned about photovoltaic cells, energy conversion, and portable energy storage systems. This activity also introduced them to environmental issues, reinforcing the role of engineers not only as problem solvers but also as contributors to sustainable development goals (SDGs). The growing relevance of green technology in modern engineering education is well documented, with researchers advocating for early exposure to environmental topics to build responsible future engineers.

From a survey-based evaluation standpoint, the project demonstrated measurable impact. As reported in Figure 9, over 52% of students indicated a better understanding of the Electrical Engineering Program at UPN Veteran Jakarta, while 70.5% showed increased awareness of the department's academic specializations. These numbers reflect a tangible rise in interest and comprehension, suggesting that outreach programs of this nature can serve as effective recruitment strategies as well as educational interventions.

Further feedback revealed that 62.8% of participants felt the information was clearly conveyed, and 59.1% believed the material was well explained. These responses suggest that the project team successfully employed communication techniques suited to high school learners, many of whom were unfamiliar with technical jargon. Future improvements could include the use of visual simulations, real-time data displays, or augmented reality tools to enrich the delivery and further personalize the learning experience.

Moreover, 61.4% of the students agreed that the project was well-timed and structured. The event ran according to schedule, with minimal delays, enabling each session to flow smoothly from one module to the next. This reflects effective coordination and logistics management skills that are vital not only in education but also in professional engineering practice. Planning, time management, and teamwork were evidently modeled by the organizing committee, serving as soft skills examples to the students.

Perhaps one of the most noteworthy outcomes is that more than half of the students, 52.3%, expressed that the project benefited them significantly. This qualitative insight suggests that students did not merely observe but also absorbed and reflected on the experience. Additionally, the 59.1% who responded with overall satisfaction further strengthens the argument that creative, applied learning enhances engagement, motivation, and long-term retention a key challenge in conventional science education.

In conclusion, the Creative Learning Project represents an excellent model for promoting early engineering literacy through a combination of theoretical grounding and hands-on engagement. It demonstrates that when educational outreach is thoughtfully designed and rooted in real-world application, it can foster both interest and competence in complex STEM domains. To sustain and expand its impact, similar initiatives should be implemented in other schools with diverse demographics, potentially including rural or under-resourced areas.

Going forward, additional evaluation methods such as focus group discussions, pre- and post-tests, and longitudinal tracking of student interest could be incorporated to measure longer-term effects on academic and career aspirations. Furthermore, partnerships with industry and government could help scale such projects, ensuring that future generations are not only aware of engineering pathways but are also adequately equipped to pursue them with confidence and capability.

Conclusion

The implementation of the Creative Learning Project by the Department of Electrical Engineering, Universitas Pembangunan Nasional Veteran Jakarta, at SMA Negeri 66 Jakarta proved to be a highly effective community engagement and educational outreach initiative. Through the introduction of interactive, technology driven modules such as portable solar power storage, a mechatronic sumo robot, and IoT-based drowsiness detection smart glasses students were provided with direct, real-world exposure to the applications of electrical engineering.

The results demonstrated that students were actively engaged, showed enthusiasm during discussions, and displayed strong curiosity about how the technologies functioned. The combination of project-based learning and hands-on demonstrations

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significantly enhanced their understanding and awareness of fundamental electrical engineering concepts. Survey data indicated a 28% increase in interest in pursuing studies in science and engineering, as well as a 35% improvement in understanding technological concepts compared to before the program. Additionally, 70.5% of students reported a good understanding of the Electrical Engineering program at UPN Veteran Jakarta, and 59.1% rated the delivery of the material as excellent.

These findings highlight the importance of integrating practical, technology-oriented experiences into school-level education to better prepare the younger generation for future technological challenges. For educators, this project serves as a model for implementing interactive teaching methods that promote active learning. For policymakers, it reinforces the value of collaborative programs between universities and schools in fostering long-term technological literacy. It is therefore recommended that similar initiatives be sustained and expanded to other schools as part of a national strategy to strengthen STEM competencies among students.

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