

Empowerment of the Learning Development Team through IoT and Web Development Skills Enhancement for Wireless Lighting Control System

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ABSTRACT : This community service program aims to enhance the skills and understanding of the Learning Development Team at SMK N 1 Sukawati in the fields of the Internet of Things (IoT) and web development. The activity focuses on training and mentoring the implementation of IoT technology using the ESP32 microcontroller, integrated with a web interface through a local server (Five Server). The implementation method consists of five stages: preparation and coordination, basic training, project implementation workshop, technical assistance, and evaluation through pre-test and post-test. The results show a significant improvement in participants' competencies, average improvement of approximately 39% in IoT knowledge, microcontroller programming, web development, and IoT-web integration. Through this program, the partner teachers successfully designed and implemented a Wireless Lighting Control System based on ESP32 independently. This program contributes to strengthening teachers' digital technology capacity and supports the integration of IoT into vocational education curricula relevant to the needs of Industry 4.0.

KEYWORDS: Internet of Things, web development, ESP32, vocational education, wireless control system.

I. INTRODUCTION

The evolution of digital technology in the Industrial Revolution 4.0 era has profoundly transformed the educational landscape, especially within vocational institutions that are mandated to prepare students for technology-driven industries. One of the key technologies supporting this transformation is the Internet of Things (IoT) an interconnected system of devices that communicate and exchange data via the internet [1], [2], [3]. IoT has become increasingly relevant in modern industries such as manufacturing, smart energy systems, logistics, and education, enabling automation, efficiency, and data-driven decision-making. Consequently, educators are required not only to understand the theoretical aspects of IoT but also to apply and integrate these technologies into teaching and learning practices [4], [5]. Vocational schools (Sekolah Menengah Kejuruan SMK) hold a strategic position in producing skilled human resources capable of meeting industry demands. However, one of the persistent challenges in vocational education in Indonesia is the limited capacity of teachers and instructors in adopting emerging technologies such as IoT and web-based applications. Teachers often lack adequate training, access to practical learning tools, and structured programs to develop competencies aligned with technological progress.

Without sufficient mastery of IoT systems and web integration, students are deprived of hands-on experiences that prepare them for the real-world digital workforce. SMK N 1 Sukawati, located in Gianyar Regency, Bali, is one of the leading vocational schools that has continuously contributed to developing competent graduates in various disciplines, including technology and engineering. The school's Learning Development Team plays a crucial role in designing, evaluating, and innovating learning models that align with current technological trends. Despite this, the team has faced challenges in mastering and implementing IoT-based learning materials due to limited exposure, minimal training opportunities, and inadequate laboratory infrastructure. This condition has resulted in a gap between the school's educational practices and the skill demands of modern industries. The rapid integration of IoT into education presents both an opportunity and a challenge. For vocational institutions, IoT can serve as a medium to introduce students to real-time data processing, remote control systems, and automation technologies. Yet, to achieve this, educators themselves must first be equipped with the competencies to design and operate IoT systems effectively. Recognizing this need, this community service program was designed as a capacity-building initiative for the Learning Development Team at SMK N 1 Sukawati. The program focused on enhancing teachers' technical and pedagogical competencies in IoT and web

development through the implementation of a Wireless Lighting Control System using the ESP32 microcontroller [6] and a local web server (Five Server). This practical project was selected as a medium for teachers to gain direct experience in connecting hardware and software components, understanding data transmission protocols, and designing interactive user interfaces for IoT-based systems [7], [8]. The specific objectives of this community empowerment activity are as follows: (1) To provide comprehensive training and mentoring for teachers in IoT fundamentals and web-based system development. (2) To develop a project-based learning framework that integrates IoT applications into vocational curricula. (3) To establish an IoT practice environment by providing learning kits and technical support. (4) To strengthen teachers' ability to independently design and implement IoT projects that align with industrial practices. The long-term impact of this activity is expected to foster a sustainable ecosystem of technology-oriented learning at SMK N 1 Sukawati. The training outcomes will serve as the foundation for developing a Mini IoT Laboratory, where both teachers and students can engage in ongoing experimentation, innovation, and applied research. This aligns with the national vision of building digitally competent human resources who are adaptive, innovative, and competitive in the era of Industry 4.0.

II. METHOD

The implementation of this community service program was designed using a structured, participatory, and project-based learning approach involving the Learning Development Team of SMK N 1 Sukawati. The applied method emphasized direct engagement, practical experience, and continuous mentoring to ensure that participants not only gained theoretical understanding but also the ability to apply IoT and web development skills in real educational contexts. The program was divided into five main stages, namely: (1) Preparation and Coordination, (2) Basic Training on IoT and Web Development, (3) Project Implementation Workshop, (4) Technical Mentoring, and (5) Evaluation [9], [10], [11]. Each stage was carefully designed to build competencies progressively, ensuring effective knowledge transfer and sustainable skill development [12].

1. Preparation and Coordination : At this initial stage, coordination meetings were conducted between the university's community service team and the school management to identify existing competencies, available resources, and specific training needs of the Learning Development Team. A needs assessment was performed to determine the level of technological readiness and potential areas for IoT integration in the school's learning environment. The university team then developed customized training materials, including IoT modules based on the ESP32 microcontroller [13], web programming tutorials, and guidelines for using local servers (Five Server). The IoT kits were designed for hands-on learning, complete with sensors, actuators, and network components to simulate real industrial conditions. This preparation ensured that both the human and technical resources were ready for implementation.

2. Basic Training on IoT and Web Development : The second phase focused on building participants' foundational knowledge through theoretical and practical sessions. The training introduced the concept of IoT architecture, network communication, and device interoperability [1], [2]. Participants learned how to configure the ESP32 microcontroller, connect it to Wi-Fi networks, and utilize sensors and actuators for automation control [6]. In parallel, the participants received training in basic web development, which included the use of HTML, CSS, and JavaScript to design user interfaces for IoT systems [7]. The integration of IoT and web development in one module allowed participants to understand how physical devices could be managed through a digital dashboard. The combination of lectures, live demonstrations, and guided practice helped bridge the gap between theory and practical application.

3. Project Implementation Workshop: The workshop stage represented the core activity of the program, where participants were guided in developing a complete IoT prototype titled "Wireless Lighting Control System." This system integrates the ESP32 microcontroller with a local web-based interface, enabling remote control of lighting devices via a browser. Participants worked collaboratively in small teams to assemble components, program devices, and test the communication between the microcontroller and the server. The workshop emphasized hands-on experience, where participants directly engaged in debugging, testing, and optimization processes. The outcome of this phase was a set of fully functional prototypes, which demonstrated the participants' understanding of end-to-end IoT implementation, from hardware assembly to web integration.

4. Technical Mentoring : Following the workshop, a continuous technical mentoring and supervision phase was conducted to strengthen the participants' mastery of the learned materials. Mentoring sessions were held both in-person and online to assist participants in troubleshooting technical issues, improving coding efficiency, and optimizing sensor performance.

The mentoring process also emphasized the pedagogical integration of IoT into classroom activities. Teachers were guided to design project-based lessons that incorporate IoT principles into existing curricula, thus promoting active and technology-driven learning environments. This mentoring stage ensured that the knowledge gained during the training could be sustainably applied within the school context.

5. Evaluation : The final stage involved evaluating the effectiveness of the training and measuring participants' progress. A pre-test and post-test approach was employed to assess the improvement in participants' understanding of IoT concepts, microcontroller programming, web development, and system integration. The evaluation results indicated a significant average improvement of 38%, demonstrating the effectiveness of the training methodology in enhancing both technical and cognitive competencies. Furthermore, qualitative feedback gathered from participants showed high satisfaction levels, with many expressing increased confidence in developing and teaching IoT-based projects.

III. RESULTS AND DISCUSSION

The implementation of this community service program at SMK N 1 Sukawati demonstrated significant outcomes in enhancing the technological competencies of the Learning Development Team, particularly in the fields of IoT and web development. The evaluation was conducted through a pre-test and post-test comparison, measuring participants' understanding across four key competency areas: IoT Knowledge, Microcontroller Programming, Web Development, and IoT–Web Integration.



Figure 1. (a) Explanation Session, (b) Practice with Partners and (a) Group Photo of Activities

Figure 1 shows several key moments during the implementation of the community service program. Subfigure (a) shows the explanation and briefing session, where the university team introduced the fundamental concepts of IoT and web development to the Learning Development Team of SMK N 1 Sukawati. Subfigure (b) captures the hands-on practice session, where participants applied the concepts learned by configuring the ESP32 microcontroller and integrating it with a local web server. Subfigure (c) presents the group photo session, taken at the end of the program to mark the successful completion of training and collaborative activities between the university team and the partner institution.

A. Evaluation Results : The results of the evaluation are presented in Table 1. The data indicate a clear increase in participants' understanding after the training program, confirming the effectiveness of the project-based learning approach implemented throughout the activity.

Table 1. Pre-Test and Post-Test Evaluation Results

Assessment Aspect	Pre-test	Post-test
IoT Knowledge	59%	95%
Microcontroller Programming	63%	89%
Web Development	57%	99%
IoT–Web Integration	60%	90%

The evaluation focused on four key aspects: IoT Knowledge, Microcontroller Programming, Web Development, and IoT–Web Integration. The comparative data between pre-test and post-test results revealed substantial improvements. In IoT Knowledge, participants showed a 36% increase, indicating better understanding of IoT principles, ESP32 hardware components, and wireless communication mechanisms. In Microcontroller Programming, the improvement reached 26%, demonstrating the participants' enhanced ability to program ESP32 devices using Arduino IDE and control sensors and actuators effectively.

The most significant improvement was found in Web Development, with a 42% increase in scores. This result reflects participants' growing ability to design and implement simple web interfaces using HTML, CSS, and JavaScript, as well as connect these interfaces with IoT devices through local servers. Meanwhile, in IoT–Web Integration, participants achieved a 30% increase, proving that they were able to combine hardware programming and web application development into a single, fully functional system.

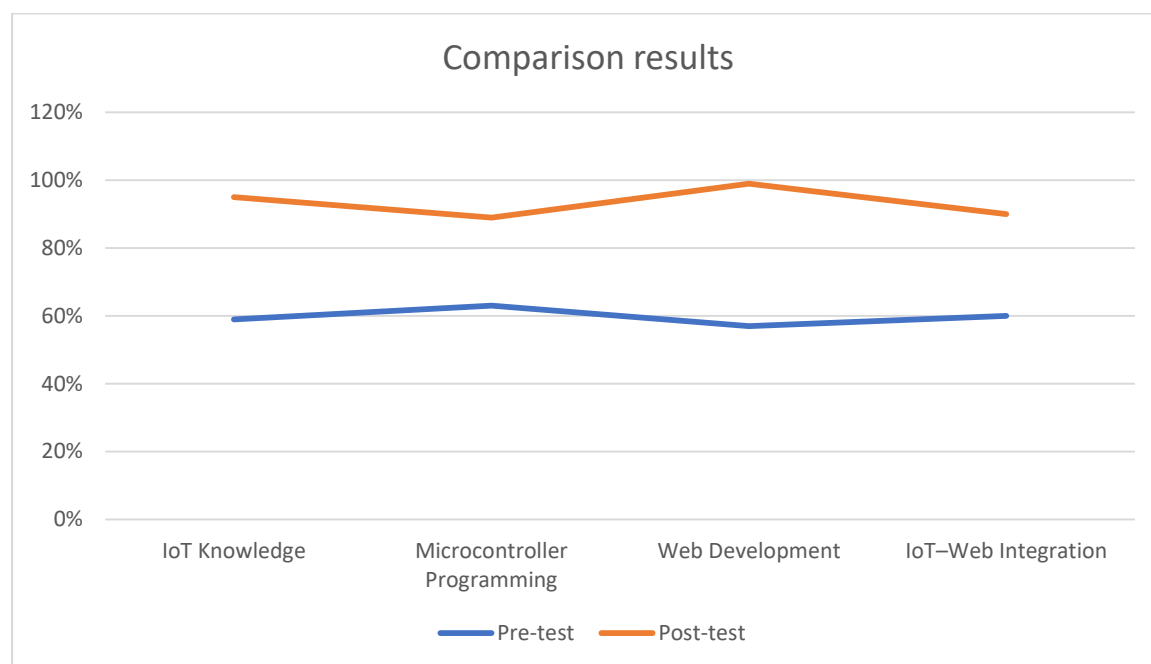


Figure 2. Comparison of pretest and posttest results

Figure 2 show a comparative analysis between the pre-test and post-test results, illustrating the improvement in participants' competencies across four key assessment aspects: IoT Knowledge, Microcontroller Programming, Web Development, and IoT-Web Integration. The horizontal axis (X-axis) represents the different assessment categories, while the vertical axis (Y-axis) indicates the achievement percentage of participants. The data show a clear upward trend across all categories, with post-test results consistently higher than pre-test scores. The most significant increase occurred in the Web Development aspect, reflecting participants' improved ability to design interactive interfaces and integrate them with IoT systems. Overall, the visualization confirms an average improvement of approximately 39% in participants' technical and conceptual competencies, validating the effectiveness of the project-based learning and mentoring approach implemented in this program.

B. Project Implementation : During the workshop and mentoring sessions, participants successfully developed a prototype of the Wireless Lighting Control System. This system utilizes an ESP32 microcontroller, sensors, and relays connected to a local Wi-Fi network, allowing lights to be controlled wirelessly through a web-based interface. The local server (Five Server) functioned as a bridge between the microcontroller and the user interface, enabling real-time communication between hardware and software. Figure 1 illustrates the design and implementation workflow of the developed IoT system.

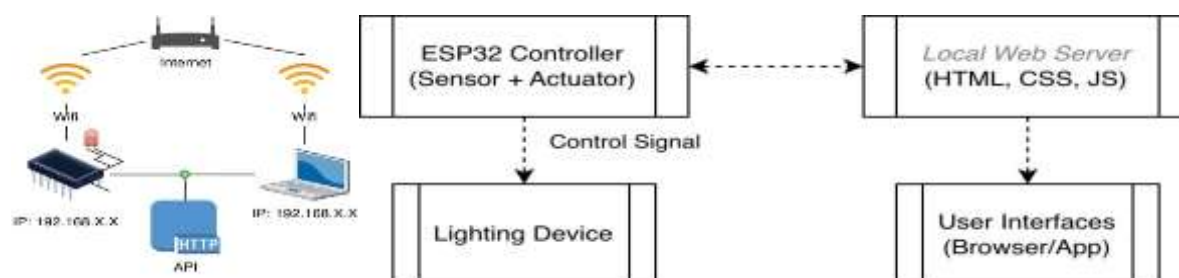


Figure 3. Flowchart of Wireless Lighting Control System

Figure 3 illustrates the implementation workflow of the Wireless Lighting Control System developed during the training. The diagram depicts the interaction between hardware and software components within the IoT architecture. The X-axis represents the process flow from sensor input, ESP32 microcontroller processing, data transmission via Wi-Fi, local web server handling through Five Server, to the final user interface output while the Y-axis reflects the functionality completion percentage throughout system testing and deployment. This visualization demonstrates the participants' ability to establish real-time data communication between the ESP32 device and the local web interface, allowing seamless wireless control of lighting systems. The integration of these elements highlights the participants' comprehensive understanding of IoT architecture, from device configuration to data-driven control applications. Through this system, teachers gained a comprehensive understanding of IoT architecture from hardware configuration, data communication, and server setup to web interface design. The project served as an integrated learning model that combines hardware and software components in a practical application.

Tabel 2. IoT Project Results

Team / Participant	Project Name	Implementation Status	Remarks
Team 1	Wireless Lighting Control	100% Functional	Web control and automation fully active
Team 2	IoT Room Monitor	80% Completed	Sensor calibration still required
Team 3	Smart Fan Controller	90% Completed	Web script adjustment needed
Team 4	IoT Lamp Scheduler	100% Functional	Fully controllable via browser interface

The main product developed during this program was a Wireless Lighting Control System, utilizing ESP32 as the main microcontroller connected to a local server. The system enables wireless control of lighting through a web-based dashboard, allowing real-time interaction between users and devices. This project provided participants with hands-on experience in developing an end-to-end IoT solution, from hardware assembly to software integration. The training outcomes demonstrate that project-based learning combined with technical mentoring is an effective approach to improving teachers' technological literacy [4], [14], [15]. The hands-on model encouraged active learning, collaboration, and self-directed exploration, which are essential for adapting to technological advancements in education. Furthermore, the program contributed to strengthening the school's technological ecosystem by initiating the development of a small-scale IoT laboratory. This lab will serve as a future training hub for teachers and students, ensuring the sustainability of IoT-based learning at SMK N 1 Sukawati . In a broader context, this community service activity aligns with the national agenda of digital transformation in education, promoting vocational schools as innovation drivers in the implementation of Industry 4.0 technologies. The empowerment of teachers through IoT and web development training not only enhances their pedagogical competence but also creates a multiplier effect by enabling them to transfer this knowledge to their students.

IV. CONCLUSION

This community service program successfully enhanced the competencies of the Learning Development Team at SMK N 1 Sukawati in the areas of Internet of Things (IoT) and web development. Through a structured five-stage method preparation, training, workshop implementation, technical mentoring, and evaluation the program achieved measurable improvements in both conceptual understanding and practical skills. The evaluation results demonstrated an average 39.5% increase in participants' competency levels, particularly in IoT knowledge, microcontroller programming, web development, and IoT–web integration. Participants were able to design and implement a Wireless Lighting Control System independently, integrating ESP32 microcontrollers with a local web interface using Five Server technology. The outcomes indicate that the integration of project-based learning with continuous mentoring effectively enhances teachers' digital literacy and technical confidence. Moreover, this initiative has led to the establishment of a mini IoT laboratory at the school, which supports the continuity of technology-based education. On a broader scale, the program strengthens collaboration between higher education institutions and vocational schools in fostering technological competence and digital innovation. The findings also suggest that empowering teachers through applied technology training generates a multiplier effect within the educational ecosystem, enabling them to transfer these competencies to their students in future learning activities. Future activities are expected to expand this initiative by integrating IoT applications with

data analytics and cloud-based systems to provide more advanced, industry-relevant learning experiences in vocational education.

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