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Enhancing the Transformation of Electrical Engineering Learning in Vocational High Schools through WOKWI Web Simulation Training in Greater Bandung

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ABSTRACT

This article reports a community service program designed to address persistent constraints in Technical and Vocational Education and Training (TVET) microcontroller and IoT practicum, including limited laboratory kits, maintenance costs, and uneven access to hardware that can reduce the frequency and quality of hands-on learning. To support project-based learning and the ongoing digital transformation of electrical engineering education, the program aimed to enhance vocational electrical teachers' competence in using a web-based simulation platform for ESP32-oriented microcontroller and IoT instruction. A one-day, hands-on workshop was developed using the GOAD (Goal–Objectives–Activities–Deliverables) framework and implemented with twenty teachers from ten vocational high schools. Activities included an introduction to WOKWI, basic C programming, microcontroller and IoT concepts, and contextual case studies such as automatic systems and flood-detection projects. Evaluation data were collected through a 12-item Likert questionnaire covering content, delivery, and practice aspects. Results showed high satisfaction, with average scores of 83.5% for content, 81.75% for delivery, and 79.25% for hands-on practice. The program indicates that WOKWI is a feasible tool to mitigate laboratory constraints and to support scalable, low-cost, and interactive IoT practicum in TVET.

Keywords: *Wokwi, Web Simulation, Vocational High School, TVET, Project Based Learning*

1. INTRODUCTION

The transformation of teaching and learning in vocational education, particularly in the field of electrical engineering, has become increasingly urgent in response to the demands of the Industry 4.0 era and the integration of digital technologies into instructional processes. The UNESCO-UNEVOC report emphasizes that the success of Technical and Vocational Education and Training (TVET) digitalization is highly dependent on teachers' digital competence and their ability to leverage technology to support learner-centered instruction **(Subrahmanyam, 2022)**. At the same time, the UNESCO TVET Strategy 2022–2029 highlights the need to strengthen the capacity of TVET teachers and institutions to adopt hybrid and online learning models, including the use of ICT-based and simulation-based learning resources to foster 21st-century skills among learners **(UNESCO, 2022)**. In the context of electrical engineering, laboratory practice and hands-on activities are critical components for developing procedural competence, problem-solving skills, and design abilities. However, limited equipment, high maintenance costs, and restricted access to laboratory time often pose substantial challenges, especially in vocational high schools (VHS) with constrained resources. A meta-analytic study shows that virtual laboratories and simulations have a significant positive effect on engineering students' learning outcomes, with strong contributions to motivation and learning engagement **(Li & Liang, 2024)**. In the vocational context, the development of practicum media based on virtual and augmented reality has been proven to facilitate electro-pneumatic practice in VHS, is considered feasible by experts, and helps students understand practicum concepts more flexibly **(Sukardjo et al., 2023)**. Another study in Indonesian vocational schools indicates that virtual laboratories can effectively support practical learning in small-scale power generation and expand students' access to experimental experiences despite limited physical infrastructure **(Marshal et al., 2021)**. In the domain of microcontrollers and embedded systems, various studies affirm that interactive simulator-based approaches can enhance the comprehension of abstract concepts and reduce the burden of errors during hardware practice. **Tang (2014)**, for example, introduced the Interactive Simulator-based Pedagogical (ISP) Approach to microcontroller instruction and found that the use of interactive simulators improved quiz performance, understanding of program structure, and received positive recommendations from the majority of students. These findings are consistent with the broader trend of using simulation media to reduce the risk of equipment damage, lower costs, and enable self-paced practice outside scheduled laboratory hours. However, at the level of vocational high school teachers—particularly electrical teachers—there remains a gap in the use of modern web-based simulators that support multiple microcontroller boards and Internet of Things (IoT) scenarios.

Wokwi emerges as one such web-based electronic simulator that enables the simulation of Arduino, ESP32, STM32, Raspberry Pi Pico, and various sensors and actuators directly through a web browser without additional installation **(CodeMagic LTD, 2021–2025)**. The official Wokwi documentation highlights its ease of access, availability of sample projects, debugging support, and distinctive features such as logic analysis and WiFi simulation for IoT projects. Practitioner experiences and user communities on the Arduino forum also show that Wokwi is perceived as a fast simulator that supports many boards and libraries, and is highly useful for schools and universities in the context of distance learning and project-based practical classes **(okayelectronics, 2021)**. Nevertheless, structured studies and training programs specifically targeting vocational high school electrical teachers—particularly within the Indonesian context—remain relatively limited, resulting in suboptimal teacher capacity to integrate Wokwi into curricula and practicum jobsheets. Responding to this gap, a community service program entitled "Web Simulation WOKWI Training for Transforming Electrical Learning in Vocational High Schools across Greater Bandung" was designed to strengthen the pedagogical and digital capacities of VHS electrical teachers through intensive training on the use of Wokwi as a web-based learning medium for microcontrollers and control systems. This program offers the following solutions: (1) introducing the concepts and practice of using the Wokwi simulator for basic and advanced experiments; (2) providing guidance in designing simulation-based electrical practicum jobsheets and modules; and (3) facilitating the implementation of Wokwi in learning scenarios that are relevant to industrial needs and VHS graduate profiles. Thus, the training is expected not only to address the challenges posed by limited physical laboratory facilities, but also to align with the global agenda for digitalization and the enhancement of TVET teachers' competencies in facing the transformation of technical education in the digital era **(Subrahmanyam, 2022; UNESCO, 2022)**.

2. METHOD

2.1 Location and Participant

The subjects of this program were 20 vocational high school teachers in the field of electrical engineering from 10 VHS in the Greater Bandung area (Bandung City, Bandung Regency, West Bandung Regency, and Cimahi City). Each school sent a maximum of two teachers as participants, selected using a purposive sampling technique, namely teachers who teach subjects related to electronics, microcontrollers, or automation. The activity was conducted offline at the Computer Laboratory, Building D, Faculty of Technology and Vocational Education (FPTK) UPI, 7th floor, on 27 May 2025.

2.2 Implementation Method

The implementation of this program employed the GOAD (Goal–Objectives–Activities–Deliverables) framework to ensure that the training was structured, systematic, and aligned with measurable outcomes **(Guo. P, 2020)**. The main goal of the program was to enhance the competence of vocational school teachers in utilizing the WOKWI web-based simulation platform for teaching electrical engineering and microcontroller applications. To support this goal, several specific objectives were formulated, including improving teachers' understanding of web-based electronic simulation, strengthening their skills in designing microcontroller projects, guiding them in developing project-based learning materials, and collecting feedback regarding the effectiveness of the training.

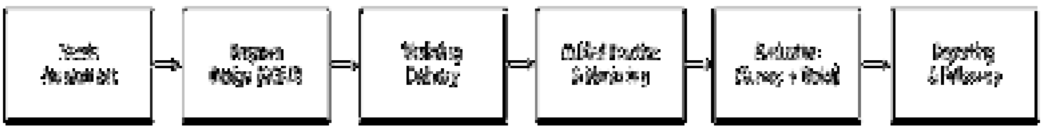

Figure 1. Simplified methodology flow of the WOKWI–ESP32 teacher workshop program

Based on Figure 1, The program followed a six-step workflow. First, a needs assessment was conducted to identify teachers' baseline competencies and common constraints in microcontroller/IoT practicum (e.g., limited hardware access). Based on these findings, the team developed the program design using the GOAD framework to align goals, objectives, activities, and deliverables **(Thomas, J. W., 2000)**. The workshop delivery then introduced WOKWI and essential ESP32-oriented concepts through short lectures and demonstrations. Participants proceeded to guided practice and mentoring, where facilitators supported hands-on tasks and debugging. Program effectiveness was measured through evaluation combining a brief satisfaction survey and task completion checks. Finally, results were consolidated in reporting and follow-up, including recommendations, learning resources/templates, and a plan for classroom implementation support.

These objectives were operationalized through a series of activities outlined in Table 1. Timeline of the WOKWI Simulation Training Program, which included registration, opening remarks, an introduction to WOKWI, foundational material on flowcharts, the C programming language, microcontrollers, and IoT, followed by hands-on simulation sessions covering multiple case studies such as automatic trash bins, automatic doors, automatic clotheslines, automatic fans, and IoT-based applications using Blynk and MQTT. Each activity in Table 1 was designed based on adult learning principles, ensuring that theoretical explanations were directly followed by practical application to support teachers' classroom implementation. The deliverables generated from this program include improved teacher proficiency in using WOKWI, the development of sample project-based jobsheets, collected evaluation data from participant questionnaires, and a follow-up plan for school-level implementation. Through the GOAD framework, the sequence of activities presented in Table 1 functioned not merely as a schedule, but as an integrated pathway toward achieving the overall goals of the program.

Table 1. Timeline of the WOKWI Simulation Training Program

No	Time	Activity	Description
1	07:30 – 08:00	Participant Registration	Re-registration, distribution of training kits and modules, introduction of participants and committee.
2	08:00 – 08:30	Opening and Welcome Remarks	Official opening, explanation of the training objectives, benefits, and expected outputs.
3	08:30 – 09:30	Session 1: Introduction to WOKWI	Introduction to the WOKWI platform, its main features, and its role in electrical/electronics learning.
4	09:30 – 10:30	Session 2: Flowchart, C Language, Microcontroller, and IoT	Basic concepts of C programming, flowcharts, ESP32 microcontroller, and an overview of IoT.
5	10:30 – 10:45	Coffe Break	Short break and informal networking among participants.
6	10:45 – 11:45	Session 3: Case Study – Automatic Trash Bin	Hands-on simulation of an automatic trash bin project using sensors in WOKWI.
7	11:45 – 12:30	Session 4: Case Study – Automatic Door	Hands-on simulation of an automatic door system based on distance or motion sensors.
8	12:30 – 13:30	Dzuhur Prayer & Lunch Break	Break for prayer, rest, and lunch.
9	13:30 – 14:00	Session 5: Case Study – Automatic Clothesline	Simulation of an automatic clothesline controlled by rain/temperature sensors.
10	14:00 – 14:30	Session 6: Case Study – Automatic Fan	Simulation of an automatic fan based on temperature sensor readings.
11	14:30 – 15:00	Session 7: Case Study – Automatic Lamp Using Blynk	Simulation of an automatic lamp integrated with WOKWI and Blynk as an IoT application.
12	15:00 – 15:30	Session 8: Case Study – Flood Detection Using MQTT	Simulation of a flood detection system using MQTT as the communication protocol.
13	15:30 – 16:00	Discussion, Evaluation, and Closing	Group discussion, reflection, completion of evaluation questionnaires, and formal closing of the event.

3. RESULT AND DISCUSSION

3.1 Implementation Program

The implementation of the program began with administrative preparation and coordination with target schools. The team first prepared and delivered formal invitation letters to 10 vocational high schools in Greater Bandung on 10–11 May 2025, requesting each school to delegate one or two teachers to participate in the training. The list of schools, along with the dates on which the invitation letters were delivered and received, is summarized in Table 2. Invitation Letter Delivery Dates, which shows that all invited schools responded and sent their teacher representatives.

Table 2. Invitation Letter Delivery Dates

No	May 10, 2025	May 11, 2025
1	SMKN 1 Majalaya	SMKN 8 Bandung
2	SMKN 1 Cimahi	SMKN 6 Bandung
3	SMKN 1 Soreang	SMKN 7 Baleendah
4	SMK TI Pembangunan Cimahi	SMKN 4 Bandung
5	SMKN 1 Cipatat	SMKN Katapang

As part of the document preparation and event administration, the team also designed participation and appreciation certificates for speakers, participants, and organizing committee members. The layout and visual identity of these certificates are shown in Figure 2 Certificate Design, which also reflects the branding of the PKM program and the host institution.

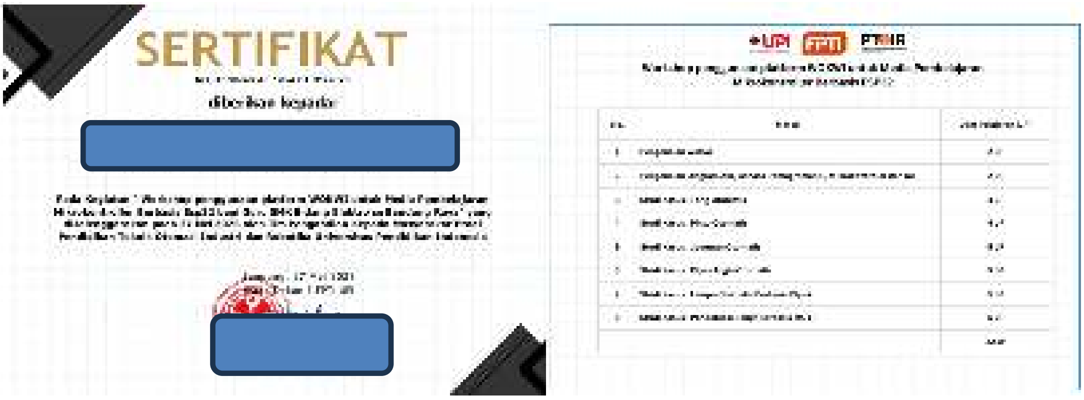

Figure 2. Certificate Design

The training was conducted face-to-face in the Computer Laboratory of Building D, FPTK UPI, 7th floor. Before the technical sessions began, each participant received a printed Wokwi training module, containing an introduction to the platform, step-by-step practice instructions, and case studies to be implemented during the workshop. The front cover of this module is presented in Figure 3 Wokwi Training Module Cover and represents one of the concrete outputs that teachers can reuse in their own schools.

Figure 3. Wokwi Training Module Cover

The one-day training ran from 07:30 to 16:00 WIB and followed a structured sequence of activities, starting from registration and opening remarks, followed by an introduction to Wokwi, fundamental concepts of flowcharts, C programming, microcontrollers, and IoT, and then a series of simulation-based case studies: automatic trash bin, automatic door, automatic clothesline, automatic fan, an automatic lamp using Blynk, and an MQTT-based flood detection system. During these sessions, the instructor actively explained concepts, demonstrated how to configure circuits and code in Wokwi, and guided participants as they implemented and tested their own simulations. This interaction is illustrated in Figure 4 Explaining to Participants, which captures the direct instructional engagement during the workshop

Figure 4. Explaining to Participants

Participants' enthusiasm was evident from their active involvement in following instructions, experimenting with simulations, and modifying the projects according to their own ideas. This engagement is shown in Figure 5 Participants Observing and Practicing the Demonstration, where teachers are seen working at the computers, focusing on building and testing various Wokwi-based projects.

Figure 5. Participants Observing and Practicing the Demonstration

At the end of the workshop, a group photo session was held, documented in Figure 6 Group Photo of Participants and Instructors, marking the formal conclusion of the training and symbolizing the strengthened professional network among teachers and between teachers and the PKM team.

Figure 6. Group Photo of Participants and Instructors

3.2 Training Evaluation Results

The effectiveness of the training was evaluated using a questionnaire completed by all participants at the end of the event. The instrument consisted of 12 items measured on a 4-point Likert scale (1 = strongly disagree, 4 = strongly agree) and was organized into three main aspects: training content, delivery of the material, and hands-on practice activities. Before analyzing the results, an interpretation framework was established, as shown in Table 3 Range of Participant Satisfaction, with the following categories: 81.26–100.00% (very satisfied), 62.51–81.25% (satisfied), 43.76–62.50% (dissatisfied), and 25.00–43.75% (very dissatisfied).

Table 3. Range of Participant Satisfaction

No	Percentage (%)	Description
1	81.26 – 100,00	Very Satisfied
2	62.51 – 81.25	Satisfied
3	43.76 – 62.50	Dissatisfied
4	25.00 – 43.75	Very Dissatisfied

For the content aspect, the items evaluated included the attractiveness of the theme, the relevance of the material to participants' needs, the organization of the material, and the clarity of the content. The detailed percentages for each item are presented in Table 4 Questionnaire – Content Aspect, which shows that all indicators fall within the 80–87% range, with an average of 83.5%, categorized as "very satisfied". This indicates that participants perceived the training content as highly relevant, well-structured, and helpful in deepening their understanding of Wokwi-based web simulation for electrical learning.

Table 4. Questionnaire – Content Aspect

No	Content Aspect Item	Percentage
1	The training theme was interesting for me	84%
2	The training material matched my needs	80%
3	The training material was well-organized	87%
4	The material was delivered clearly and provided good understanding for me	83%
Average		83.5%

In the delivery aspect, the items addressed the instructor's mastery of the material, adequacy of time allocation, clarity of explanations, and responsiveness in facilitating discussion and feedback. The recap shown in Table 5 Questionnaire – Delivery Aspect reports an average score of 81.75%, which also falls into the "very satisfied" category. Participants appreciated the instructor's strong mastery and clear explanations, although some comments suggested that extending the time for discussion and Q&A would further enhance the learning experience.

Table 5. Questionnaire – Delivery Aspect

No	Delivery Aspect Item	Percentage
5	The instructor had a strong understanding of the material delivered	85%
6	The time allocated by the instructor to present the material was sufficient	82%
7	The instructor delivered the material well and it was easy to understand	83%
8	The instructor facilitated discussions and provided constructive feedback	77%
Average		81.75%

For the hands-on practice aspect, the questionnaire evaluated the quality of the practice modules, their ease of understanding, the support provided by assistant instructors, and the sufficiency of time allocated for practice. As shown in Table 6 Questionnaire – Practice Activities Aspect, the average score for this dimension was 79.25%, which is categorized as "satisfied". The highest ratings were given to the support from assistant instructors and the clarity of the modules, while the lowest score (73%) was recorded for the time allocation for practice, indicating that participants would prefer a longer duration for hands-on work to explore Wokwi simulations more deeply.

Table 6. Questionnaire – Practice Activities Aspect

No	Practice Activity Item	Percentage
9	The provided module had good quality	79%
10	The provided module was easy to understand	82%
11	Assistant instructors facilitated the practice activities well	83%
12	The time allocated for hands-on practice was sufficient	73%
Average		79.25%

3.3 Overall Interpretation and Implications

Taken together, the results from Table 3 (Range of Participant Satisfaction) and Tables 4–6 (Questionnaire results for content, delivery, and practice aspects) show that the training achieved "satisfied" to "very satisfied" ratings across all dimensions assessed. The highest scores were obtained in the content and delivery aspects, confirming that the workshop design, topics, and instructional approach matched the needs and expectations of VHS teachers. The slightly lower, though still positive, scores in the hands-on practice aspect highlight a concrete area for improvement—namely, extending practice time or providing additional follow-up activities to enable deeper exploration of Wokwi projects. These findings suggest that the Wokwi web simulation platform is perceived as useful and pedagogically valuable by vocational teachers and has strong potential to be integrated into project-based and IoT-oriented learning in electrical subjects. The workshop not only increased teachers' digital competence, but also provided them with ready-to-use materials (modules and case studies) and practical experience that can be directly transferred to their classrooms. Moving forward, future iterations of the program can be strengthened by adding post-training mentoring, online resource repositories, and blended learning formats, to further support sustained implementation of Wokwi in vocational schools.

4. CONCLUSIONS

In conclusion, the WOKWI Web Simulation Training for Transforming Electrical Learning in Vocational High Schools across Greater Bandung successfully achieved its main objective of enhancing teachers' competence in using web-based simulation to support electrical and microcontroller instruction. The workshop was well received, as reflected in consistently high satisfaction scores across content, delivery, and hands-on practice, indicating that the training theme, materials, and instructional approach were relevant, clearly presented, and practically useful for VHS teachers. The provision of a structured module and a series of contextual case studies (automatic systems and IoT-based projects) equipped participants with ready-to-implement learning resources for project-based and problem-based learning in their classrooms. Although time allocation for hands-on activities was perceived as somewhat limited, this feedback provides a clear direction for future improvements through extended practice sessions and follow-up mentoring. Overall, the program demonstrates that WOKWI is a feasible and effective tool for mitigating laboratory constraints in vocational schools and represents a strategic step toward the broader digital transformation of electrical engineering education at the TVET level.

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