Hands-On Training for Physics Teachers: Project-Based Learning with Solar Energy Systems

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Abstract

This community service program was designed to enhance the pedagogical and technological competencies of physics teachers in MGMP Fisika Jakarta by introducing them to sensor and microcontroller-based learning media. The training consisted of eight structured sessions, beginning with an introduction to microcontroller fundamentals and various types of sensors, including their working principles and real-world applications in physics education. Participants then engaged in hands-on training on operating microcontrollers and constructing measurement instruments, such as temperature and distance sensors, integrated into microcontroller systems. Teachers were also guided through the process of developing simple, sensor-based educational devices tailored to classroom use. To support effective implementation, the training included the creation of a practical guidebook and the production of demonstration videos that could be used in future instruction. Futhermore, participants learned how to build and utilize a Learning Management System (LMS) using Moodle to digitize and manage learning content. The training was delivered through a collaborative, workshop-based approach that encouraged active participation and creativity. As a result, teachers not only improved their technical skills but also gained the ability to integrate technology into physics instruction in innovative ways. The program demonstrated that equipping teachers with skills in sensor and microcontroller technology can significantly enrich STEM-based teaching and learning experiences.

Keywords: Teacher Training, Microcontroller, Sensor-Based Learning Media

INTRODUCTION

Physics is one of the branches of science that studies environmental issues and the climate crisis. However, this discussion has only been addressed theoretically so far, even tho students need real-world explanations and conceptual approaches related to their daily lives. To overcome this problem, teaching aids or learning media are needed to help visualize the concept. The learning media developed should be learning media that integrates modern technology in line with

technological advancements. This is because conventional learning media such as books are no longer effective for use in learning.
The rapid advancement of technology in the 21st century has transformed the way education is delivered, especially in the field of science. Physics, as a subject that often involves abstract concepts and mathematical formulations, can be challenging for students to fully grasp through traditional lecture based methods alone (Baotong et al., 2025). To address these challenges, educators are increasingly turning to interactive and technology enhanced learning tools. Among these innovations, microcontroller based devices integrated with sensors offer a highly engaging way to visualize physical phenomena in real time. These tools not only bridge the gap between theory and practice but also create an active learning environment that fosters student curiosity and critical thinking (Organtini & Tufino, 2022).

In the context of modern physics education, the adoption of sensor and microcontroller technologies (Çoban et al., 2022) aligns closely with the STEM (Science, Technology, Engineering, and Mathematics) approach, which emphasizes interdisciplinary learning and real-world applications . For example, a microcontroller-based system can be used to measure the coefficient of static friction, monitor temperature changes, or track the velocity of moving objects turning theoretical formulas into tangible, observable data. This hands-on integration of technology enables students to connect abstract principles with practical experiments, making learning more relevant and impactful (García-Tudela & Marín-Marín, 2023). However, the successful implementation of such tools requires teachers to possess both the technical know how and the pedagogical skills to integrate them effectively into their lessons (Al-Abdullatif & Gameil, 2021).

One learning approach that can help and serve as a means for teachers to learn about technology-integrated learning media is the Project-Based Learning model. The PjBL learning model is a learning model that can help teachers learn a subject matter thru a project approach and can help students understand a learning material thru a project approach. Project-based learning models can be implemented in activities such as training to improve teachers' abilities in a subject matter. Training activities can be designed in such a way that they are equipped with the delivery of material, simulations, and the creation of a final product that can be used as a learning medium in schools.

Despite the clear benefits, many physics teachers face barriers in adopting microcontroller based teaching media (Noor & Saibon, 2023). Common challenges include a lack of familiarity with programming languages, limited access to hardware components, and insufficient training opportunities that combine both technical and instructional elements. In many cases, professional development programs focus primarily on theoretical aspects without giving participants enough time for hands-on experimentation (Tsai, 2023). As a result, teachers may leave training sessions with conceptual knowledge but without the confidence to design and implement technology driven experiments in their classrooms (Alotaibi & Alshehri, 2024).

Hands-on training programs provide a practical solution to this gap by immersing teachers in the process of designing, assembling, and programming microcontroller based devices themselves. Such programs emphasize learning by doing, allowing participants to troubleshoot errors, adapt designs to suit their instructional needs, and immediately see the results of their work. This approach not only builds technical competence but also strengthens problem solving skills and creativity (Abendaño, 2024). Furthermore, by working collaboratively during the training, teachers can share strategies, insights, and classroom applications building a professional learning community that supports long term innovation (Ling et al., 2022).

The program described in this article was specifically designed to equip physics teachers with the skills and confidence to integrate sensor and microcontroller-based tools into their teaching (Tupac-Yupanqui et al., 2022). Focusing on real-world applications in physics experiments, the training combined theoretical sessions with extensive practice using Arduino-based systems and various sensors (Vitkóczi et al., 2025). By the end of the training, participants were expected to produce a functional teaching media prototype that could be directly applied in their classrooms. This initiative represents an important step towards modernizing physics education and ensuring that students are prepared to engage with science in a technology-driven world.

METHOD

The training was conducted for a group of physics teachers from various schools, aiming to improve their competence in using microcontroller-based learning media. The methodology included an introduction to microcontroller concepts, an overview of different sensor types, and a step-by-step guide to circuit assembly. Participants then learned how to integrate sensors into the Arduino microcontroller, program them using the Arduino IDE, and test their projects. The training applied the STEM-based approach, ensuring that participants engaged in activities involving science concepts, technological tools, engineering processes, and mathematical analysis.

RESULTS AND DISCUSSION

The Hands-on Training in Sensor and Microcontroller-Based Physics Teaching Media, conducted as part of the Research and Community Service (P2M) program, was implemented using a training method that combined lecture-based material delivery with direct hands-on practice. The program was attended by 45 participants, comprising high school physics teachers who are members of the Physics Subject Teacher Forum (MGMP) of DKI Jakarta.

The activity commenced with a 25-minute lecture session entitled Introduction to Basic Microcontroller. This session provided participants with fundamental knowledge of microcontrollers, covering their functions, operating principles, and examples of their application in the design of sensor-based physics teaching media. The lecture was complemented with detailed explanations of commonly used hardware and software components, ensuring that participants acquired a comprehensive understanding prior to engaging in the practical component of the training.

Figure 1. Lecture Session

During the laboratory session, teachers learned to assemble components into a system circuit according to the instructions in the provided module. The components used are Arduino Uno, 5V Mini Solar Panel, LDR Sensor, Voltage Sensor, DHT11 Sensor, I2C LCD, Relay, Jumper Wires, 12V DC Fan, Battery, and Protoboard. After assembling the circuit according to the given schematic, the teacher learned computer programming using the Arduino IDE software on a laptop. This programming system functions to provide algorithms to the Arduino so that it works according to the program that has been created. The program logic in this system is as follows: the Arduino reads several sensor measurement results, namely the voltage sensor (which provides the voltage generated by the solar panel), the LDR sensor (which provides an analog signal), and the DHT11 sensor (which provides temperature and humidity). The sensor readings are displayed on the I2C LCD connected to the Arduino. The Arduino program also includes conditional logic: when the temperature measurement result is greater than 31°C, the relay will activate and connect the battery to the fan, allowing the fan to turn on. However, when the temperature measurement result is less than 31°C, the fan will not turn on.

Figure 2. The practical sessions

Next, for the data collection or tool testing stage, which is done with additional materials, namely candles and study lamps. First test: The teacher measured the temperature and humidity by lighting a candle near the DHT11 sensor. Second test: The teacher measured the light intensity at various brightness levels of the study lamp, along with the voltage generated by the solar panel due to changes in light. The final stage is for the teachers to conduct a joint analysis of the test results that have been carried out.

The outcome of the laboratory session activity is that teachers can design circuits according to the given circuit diagram. The results of the first test, the logic system related to fan automation turning on when the temperature reaches 31℃, were appropriate and worked well. The results of the second test showed that teachers gained a better understanding of solar panel practices, namely that the higher the level of brightness, the greater the voltage produced. These results enhance teachers' understanding of the practical application of renewable energy concepts in converting light energy into electrical energy.
During the practical sessions, each team engaged in designing microcontroller-based systems integrated with various types of sensors, testing the performance of their designs, and conducting data analysis to verify that the systems operated as intended. Upon the completion of all laboratory the program concluded with a joint quiz undertaken simultaneously by all participants, serving as a final evaluation of the knowledge and skills acquired during the training.

During the training, teachers actively participated in designing, assembling, and testing small-scale solar energy modules, including solar panels, charge controllers, and load circuits. This activity not only enhances their conceptual understanding of photovoltaic principles but also strengthens their problem-solving and collaboration skill two key competencies in 21st-century education. The project based learning approach has proven effective in fostering inquiry and reflection skills (Chen, 2021). Teachers are invited to identify real-world problems, such as designing a solar-powered lighting system for school laboratories, and work together to find practical solutions (Carranza et al., 2024). Thru this process, teachers themselves experience the inquiry-based learning cycle that they are also expected to implement with their students.

Additionally, the integration of solar energy systems provides high environmental relevance, motivating teachers to emphasize sustainability issues in the learning process (Altassan, 2023). Participants expressed increased awareness of global energy challenges and the importance of fostering ecological responsibility among students. These results support the view that renewable energy topics can serve as an entry point for contextual physics learning, connecting scientific principles with social and environmental awareness.

Overall, this training successfully blended the principles of Project-Based Learning with renewable energy education, resulting in a holistic professional development experience. Similar programs in the future could be further developed by adding digital monitoring technology (such as Arduino-based solar data logging) or cross-disciplinary integration between physics, environmental science, and educational technology.

CONCLUSIONS

The hands-on training based on Project-Based Learning (PjBL) with the theme of solar energy systems has had a positive impact on improving the competence of physics teachers, both in terms of conceptual knowledge and practical skills. Thru the activity of designing, assembling, and testing a simple solar energy system, teachers gain a deeper understanding of the working principles of renewable energy while also improving their ability to implement project-based learning in the classroom. Overall, this training activity demonstrates that teacher professional development thru hands-on experience and project-based learning is an effective strategy for strengthening pedagogical competence while integrating science, technology, and environmental awareness. For the sustainability of the program, it is recommended that similar training be conducted periodically with the support of digital technology such as Arduino for monitoring solar energy data, as well as cross-disciplinary collaboration between physics, engineering, and environmental education.

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