

Teacher Competence Enhancement with Arduino and AI-Based Gas Detection

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ABSTRACT

The Indonesian government has implemented a deep learning approach across four key frameworks: pedagogical practices, learning environments, learning partnerships, and digital utilization. However, challenges such as limited teacher skills and inadequate infrastructure, particularly in technology, hinder its full implementation. This study aims to explore how teachers at the Community Learning Center (PKBM) in Cibeber Subdistrict, Cianjur Regency, develop learning media based on an automated system using the Wokwi simulator and Arduino IDE. Artificial intelligence tools, such as ChatGPT, support the creation of this media. A qualitative descriptive approach was employed, with data collected through direct observation of 15 teachers from three PKBMs. The research focused on the development of a gas detection device using the four pillars of computational thinking: abstraction, decomposition, algorithmic thinking, and pattern recognition. Data analysis followed the Miles & Huberman method, which includes data collection, reduction, presentation, and conclusion drawing. Results show that teachers successfully followed all stages of tool development, achieving the following indicators: abstraction (70%), decomposition (85%), algorithmic thinking (78%), and pattern recognition (81%). Despite coming from non-science backgrounds with no prior programming experience, teachers were able to design gas detection tools (LPG, alcohol, smoke, and carbon monoxide) and adapt their skills to create a smart parking system project. This study demonstrates how AI tools, simulators, and hands-on practice can bridge teachers' technical limitations, enhancing their creativity and ability to develop innovative, technology-based learning materials.

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Introduction

The Indonesia has recently introduced a deep learning approach into its education system, focusing on four key frameworks: practical pedagogy, learning environment, learning partnerships, and digital utilization. Although deep learning itself is not a new concept, its explicit incorporation into the national curriculum marks a significant shift (Badan Standar Kurikulum dan Asesmen Pendidikan, 2025). However, challenges remain, particularly in terms of teacher readiness and infrastructure for digital utilization. Adzkie et al. (2024) found that 274 teachers in Jambi exhibited low technological skills, and a similar study by Rajapakse et al. (2024) on 1,300 ICT teachers in Sri Lanka highlighted low self-efficacy among educators. Furthermore, Pratiwi et al. (2025) noted a gap in the availability of technological devices, especially in rural areas, which hampers the development of technology-based learning. As a result, teachers need targeted training and support to utilize available technology effectively.

Several initiatives have aimed to assist teachers in integrating technology into learning. Kamala & Ni'mah (2022) supported ICT applications, including developing student worksheets, using Google Meet, and creating learning videos. Saputra & Putra (2022) mentored elementary teachers on interactive PowerPoint features, while Sugiarsa et al. (2024) guided teachers in using artificial intelligence to enhance the creation of learning tools.

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Initial observations and interviews with teachers at community learning centers (PKBM) in Cibeber Subdistrict revealed that they are familiar with AI tools such as ChatGPT, Meta, Gemini, Perplexity, Canva AI, and Blackbox AI. Teachers have used these tools for preparing materials and generating questions but face challenges in utilizing AI for more complex tasks, particularly in creating educational materials, which often require more advanced prompts or programming (coding).

In response to the recent integration of coding and AI in Indonesia's education system, this study investigates how PKBM teachers in Cibeber Subdistrict develop Arduino-based learning media using AI tools. Specifically, the study explores how teachers apply computational thinking during the process of creating teaching materials with the Wokwi simulator and examines the role of AI in enhancing teachers' creativity and problem-solving abilities.

Methods

This study is a qualitative descriptive study. The subjects of this study are 15 teachers from Community Learning Centers (PKBM) in Cibeber District, Cianjur Regency. Participants were selected based on their familiarity with technology and their involvement in previous training sessions on educational technology. This study was conducted on July 1, 2025. The research focuses on the process by which teachers create a gas detection learning media project using the Wokwi simulator and hands-on manufacturing practices.

Research data were obtained through direct observation of teachers during the creation of gas detection devices for LPG, carbon monoxide, alcohol, and smoke. The research instrument used was a performance assessment sheet, which evaluated the design and functionality of the simulators and the final products. The performance indicators included the effectiveness of the project's design, the teachers' understanding of computational thinking, and the technical accuracy of the tools created. The validity of this assessment sheet was ensured through a peer review process with experts in both technology and education, and its reliability was tested by conducting a pilot study prior to data collection.

Data analysis was conducted using Miles & Huberman's qualitative data analysis method, which includes data collection, data reduction, data presentation, and drawing conclusions. The process of creating the detection devices was divided into two stages. In the first stage, teachers used the Wokwi simulator to design gas detection and smart parking system projects. In the second stage, they implemented the designs by building gas detection systems using the Arduino IDE application. The materials used were Arduino Uno boards, jumper cables, USB Type B cables, and MQ-2 gas sensors.

The choice of the Wokwi simulator and Arduino IDE was based on their user-friendly interface, accessibility for beginners, and compatibility with the learning objectives of integrating computational thinking into practical applications. The Wokwi simulator, in particular, was selected due to its ability to provide an interactive, virtual environment for testing and debugging, which is crucial for teachers with limited programming experience. The Arduino IDE was chosen for its widespread use in educational settings and its versatility in creating a variety of projects, from simple to complex. Identified, of which 25 were deemed the most suitable for further analysis (Wahyuningtyas & Kristin, 2021).

Results and Discussions

This study observed the process of 15 teachers from three Community Learning Centers (PKBM) in Cibeber District, Cianjur Regency, as they developed gas detection learning media. The teachers involved were not limited to science educators but included teachers from various disciplines. Figure 1 presents the results of the open questionnaire on the subjects taught by the participants using the mentimeter.com platform.



Figure 1. Subjects Taught by Teachers

The research began with an introduction to the potential and dangers of using artificial intelligence (AI), emphasizing ethical considerations in its use, as recommended by government directives (Badan Standar Kurikulum dan Asesmen Pendidikan, 2025). Teachers were then guided in creating a gas detection device project using the Wokwi simulator, emphasizing the four pillars of computational thinking: abstraction, decomposition, algorithmic thinking, and pattern recognition (Badan Standar Kurikulum dan Asesmen Pendidikan, 2025). These concepts were introduced progressively to help teachers understand the workflow of the tool and recognize systematic thinking patterns in developing basic technology projects. Table 1 shows the achievements of teachers in developing the gas detection system project.

Table 1. Teacher Achievement Based on Computational Thinking Indicators

| Indicator | Sub Indicator | Percentage |
|----------------------|--|------------|
| Abstraction | Determine solutions to problems based on automation and IoT systems | 70% |
| Decomposition | Determine the necessary components Develop the system workflow | 85% |
| Algorithmic Thinking | Develop programming code Test and revise code logic based on simulation results | 78% |
| Pattern Recognition | Analyze simulation data Generalize experiences | 81% |

The lowest score (70%) was recorded for abstraction. While teachers were introduced to abstract concepts, this indicator was more challenging for non-science teachers who have less exposure to technology development. As noted by Wulandari (2019), abstraction requires teachers to think beyond the immediate learning context, which becomes challenging when they are unfamiliar with technological applications. Despite this, teachers were able to grasp the essential components of the problem and use automation to address everyday issues, such as detecting LPG leaks or carbon monoxide.

Decomposition, on the other hand, had the highest score (85%). This indicates that teachers could successfully break down a complex project into smaller, manageable tasks. Teachers demonstrated their ability to apply systematic thinking an essential component of computational thinking—by identifying the various components and steps required to complete the project. According to Chevalier et al. (2022), decomposition allows individuals to solve problems more efficiently by breaking them down into smaller, more manageable units. This was evident in teachers' ability to identify the necessary components (sensors, wires, and microcontrollers) and develop a logical workflow for their projects.

Algorithmic thinking scored 78%. Teachers translated the working logic into a structured program, working with ChatGPT to create and revise the program code. This stage involved both the development of algorithms and the testing of the program to ensure it met the desired output. Teachers used AI to help write code but also had to ensure the accuracy of data output, such as converting sensor readings into appropriate units like parts per million (ppm). The ability to understand and troubleshoot the program was vital in this phase, reinforcing the importance of a solid foundational understanding of programming.

Finally, pattern recognition achieved a score of 81%, reflecting that teachers were able to generalize from their experiences in creating the gas detection device and apply these insights to other projects, such as a smart parking system. This shows that teachers were able to transfer the knowledge they gained from one context to another, reinforcing the idea that computational thinking is not just about solving a single problem but recognizing patterns across multiple situations.

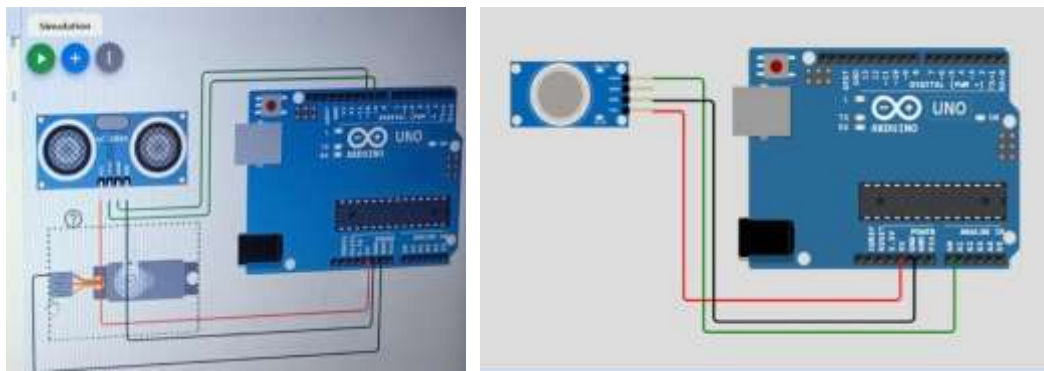


Figure 2. Process of Creating a Gas Detection Device Simulation (a); Process of Creating an Automatic Parking System Simulation (b)

Figure 2 illustrates the progression from the gas detection device project (2a) to the smart parking system (2b), showing how teachers could adapt their earlier experiences to create new systems. The teachers initially created gas detection systems using the Wokwi simulator, followed by transitioning to a physical implementation using the Arduino IDE application. In the practical stage, teachers connected the components—Arduino Uno, MQ-2 gas sensors—and uploaded the pre-tested program to the Arduino board. Most devices functioned correctly, although one sensor produced inaccurate readings due to a hardware malfunction, which was corrected using a different sensor (Meylani, 2024).

These findings emphasize that even teachers with no deep prior knowledge in programming or technology were able to create functional educational media. AI tools like ChatGPT were pivotal in helping them bridge technical knowledge gaps, as these tools facilitated the creation of complex systems that they otherwise might not have been able to develop.

However, it is crucial to note that while AI played a supportive role, teachers still needed a strong foundational understanding of the logic and concepts behind the systems they were building.

In line with Rachmadtullah et al. (2024) and Hidayati et al. (2025), these results confirm that AI can support teachers in developing project-based learning media and simulations. Even teachers without specialized technical expertise can utilize AI to better understand programming logic and create functional educational tools. AI, therefore, acts as a bridge, enabling teachers to develop creative and relevant educational media while also enhancing their problem-solving skills and critical thinking (Amer et al., 2023).

The ability to develop learning media is essential, particularly in science education, where the latest Merdeka Curriculum emphasizes digital technology for data collection, analysis, and presentation. This aligns with Fadiya & Satianingsih (2025), who found that interactive media positively impacts student learning outcomes and critical thinking in science education. Teachers' ability to integrate scientific principles with digital technology not only enhances classroom learning but also lays the groundwork for future research and applications in automation and technology integration in education (Bresnahan et al., 2023; Lockridge & Dorgan, 2024).

Conclusions

This study shows that teachers at the Community Learning Center (PKBM) in Cibeber Subdistrict, Cianjur Regency, successfully developed automated system-based learning media using project-based approaches and simulators, despite lacking programming backgrounds. The integration of computational thinking pillars and AI tools, such as ChatGPT, helped teachers understand system logic and design contextually appropriate solutions. Simulators like Wokwi and the Arduino IDE bridged the gap between theory and practice, enabling the creation of more practical learning materials. Further research should explore the long-term impact of AI-supported learning on teachers' technology confidence, scalability of this approach in diverse contexts, and its effectiveness in enhancing student engagement and learning outcomes.

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