

Enhancing Computer Technology Student Competencies Through Project-Based Learning in Microprocessor Systems

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ABSTRACT

This study aimed to describe the implementation of Project-Based Learning (PjBL) in the Microprocessor Systems course to enhance the competencies of Computer Technology students through the development of an Arduino Uno-based automatic plant watering system. The study employed a descriptive approach by implementing PjBL activities involving project planning, sensor circuit design, microcontroller programming, system testing, and project presentation. The participants were Computer Technology students enrolled in the Microprocessor Systems course. The project utilized an Arduino Uno as the main controller integrated with a soil moisture sensor, a relay module, a mini water pump, and supporting components. Data were collected through direct observation, project assessment, and documentation of learning activities. The assessment focused on students' abilities in hardware design, sensor calibration, program implementation, and system testing. The findings indicated that students actively participated throughout the learning process and successfully completed the assigned projects. The implementation of PjBL not only improved students' understanding of microcontroller concepts but also fostered technical competencies, problem-solving skills, collaboration, and critical thinking. Therefore, Project-Based Learning using Arduino Uno can be considered an effective instructional strategy for supporting competency-based learning aligned with industry needs.

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INTRODUCTION

The rapid advancement of technology in the era of the Industrial Revolution 4.0 requires higher education institutions to produce graduates who not only possess strong theoretical knowledge but also demonstrate 21st-century skills. Therefore, the learning process in higher education should be directed toward a student-centered learning approach to develop competencies that align with the demands of the workforce and ongoing technological advancements (Fatimah et al., 2024).

One of the core courses in the Computer Technology Study Program that plays a significant role in developing these competencies is the Microprocessor Systems course. However, the teaching of Microprocessor Systems is often still dominated by conventional lecture-based methods, resulting in passive student participation. Consequently, the development of more contextual learning media and instructional tools is essential to help students understand the integration of microprocessor technology with real-world applications (Isnaini et al., 2025).

One alternative instructional model that can be implemented to address these challenges is Project-Based Learning (PjBL). This model places projects at the center of the learning process, enabling students to gain meaningful learning experiences through the stages of planning, implementation, testing, and evaluation. Research conducted by Lesmana and Jaedun (2015) demonstrated that the implementation of PjBL effectively improves student learning outcomes because students actively engage in completing project-based tasks related to their field of expertise.

The effectiveness of Project-Based Learning has also been demonstrated in electronics education. Najamuddin and Wahrini (2024) reported that the implementation of the PjBL model in the Microprocessor Systems course had a positive impact on students' learning outcomes. Furthermore, Fatimah et al. (2024) stated that integrating Project-Based Learning into instructional activities enhances students' non-technical competencies by promoting teamwork, communication skills, responsibility, and decision-making abilities. Based on these perspectives, this study examines the implementation of PjBL through an automatic plant watering system to improve the competencies of Computer Technology students.

METHODS

This study employed a descriptive method with an implementation approach to describe the application of the Project-Based Learning (PjBL) model in the Microprocessor Systems course (Arikunto, 2019). The learning activities were carried out during the even semester of the 2025/2026 academic year in small groups consisting of 3 to 5 students.

The learning process followed the Project-Based Learning syntax, which included: (1) identifying the problem or project to be completed; (2) planning the project; (3) developing an implementation schedule; (4) carrying out the project; (5) testing and presenting the project outcomes; and (6) evaluating both the learning process and the project results (Kokotsaki et al., 2016). The project developed in this study was an automatic plant watering system using an Arduino Uno, a soil moisture sensor, a relay module, and a water pump.

Research data were collected through classroom observations, activity documentation, and project assessments. The assessment criteria were structured specifically around:

Hardware Design, Sensor Calibration, Program Implementation, and System Testing. The collected data were analyzed descriptively.

RESULTS AND DISCUSSION

1. Result

The Project-Based Learning module was carried out across six distinct student groups (K1 to K6). Each group was responsible for designing hardware circuits, calibrating soil moisture sensors, writing microcontroller code, and testing the automatic watering system.

Student performance was evaluated based on four new specific categories tailored to automated system implementation:

Table 1. Project Assessment Results

Group	Hardware Design	Sensor Calibration	Program Implementation	System Testing	Final Score
K1	85	88	82	90	86.25
K2	90	85	89	92	89.00
K3	80	82	78	85	81.25
K4	88	86	85	89	87.00
K5	92	90	91	94	91.75
K6	86	84	83	88	85.25

Based on the assessment results in Table 1, Group K5 achieved the highest final score of 91.75, while Group K3 obtained the lowest score of 81.25. Overall, all groups successfully completed the project with satisfactory performance.

2. Discussion

The implementation results indicate that Project-Based Learning (PjBL) enhanced students' active involvement and participation in the process of designing, assembling, programming, and validating microcontroller-based hardware systems. Through this learning approach, students were encouraged to apply theoretical concepts to practical situations, particularly in developing an automatic soil moisture monitoring and control system. The project-based activities provided students with opportunities to improve their technical skills, problem-solving abilities, critical thinking, and collaboration throughout the implementation process. Furthermore, students were able to gain direct experience in integrating hardware components, including microcontrollers, soil moisture sensors, and output devices, into a functional system.

The system testing aspect achieved a high average score across all groups, indicating that most students successfully developed and tested functional hardware capable of responding to changes in soil moisture levels. The results demonstrate that the majority of students were able to integrate the system components properly and establish the relationship between sensor readings and the system's operational response. During the testing process, students evaluated the system's performance by observing sensor readings

under different soil moisture conditions and verifying whether the hardware responded according to the predetermined threshold values. This activity helped students understand the importance of hardware integration, system validation, and performance evaluation in the development of microcontroller-based applications.

However, the program implementation and sensor calibration categories required additional guidance and support from the instructor. Several students experienced difficulties in developing the program logic, interpreting sensor data, and establishing appropriate threshold values for distinguishing between wet and dry soil conditions. These challenges suggest that students' understanding of programming structures, conditional statements, analog-to-digital conversion, and sensor characteristics still needs to be strengthened. In particular, variations in sensor readings under different soil conditions made it necessary for students to conduct repeated measurements and adjustments to obtain more reliable results. Consequently, the calibration process became an important learning activity that enabled students to understand the relationship between environmental conditions, sensor outputs, and the decision-making logic implemented in the microcontroller program.

Overall, the findings suggest that Project-Based Learning provides a valuable instructional approach for improving students' practical competencies in microcontroller-based hardware development. Although most groups demonstrated satisfactory performance in assembling and testing their systems, the difficulties encountered during programming and sensor calibration highlight the need for more structured instructional support. Future implementation of this learning approach could include additional programming exercises, step-by-step sensor calibration demonstrations, sample code analysis, and guided troubleshooting activities before students begin independent project development. By incorporating these improvements, Project-Based Learning is expected to facilitate a more balanced development of students' hardware assembly, programming, calibration, and system testing skills. This approach can also promote greater student independence and confidence in solving practical engineering problems, particularly in the development of sensor-based automation systems for real-world applications.

CONCLUSION

The implementation of Project-Based Learning (PjBL) through the development of an automatic plant watering system provided students with practical learning experiences that integrated theoretical knowledge with hands-on engineering skills. Throughout the project, students were actively involved in hardware design, component assembly, programming, sensor calibration, and system testing. These activities enabled students to apply fundamental concepts of microcontrollers, electronic circuits, and sensor-based automation to develop a functional system. The project was evaluated across four main parameters: hardware design, sensor calibration, program implementation, and system testing, which collectively reflected students' abilities to design, develop, and validate a microcontroller-based application.

The results demonstrated that students gained valuable experience in assembling hardware components, integrating soil moisture sensors with microcontrollers, and implementing program logic to control the water pump automatically. In the hardware

design and system testing categories, students learned to verify component connections and evaluate system responses under different soil moisture conditions. However, some students required additional guidance in sensor calibration and program implementation, particularly in interpreting sensor readings, determining appropriate threshold values, and developing accurate control logic. These challenges encouraged students to conduct repeated measurements, identify programming errors, and make necessary adjustments to improve system performance. Consequently, the project supported the development of technical competencies in hardware integration, programming, troubleshooting, and system validation.

Overall, the implementation of PjBL demonstrated its potential to enhance students' technical and non-technical competencies through active participation in practical engineering activities. In addition to developing skills in hardware design, sensor calibration, programming, and system testing, students had opportunities to strengthen their problem-solving abilities, critical thinking, creativity, collaboration, and responsibility. The project also encouraged students to take a more active role in identifying problems and developing solutions independently. Therefore, the automatic plant watering system can serve as an effective learning medium for microcontroller and embedded systems courses. Nevertheless, providing more structured guidance in programming and sensor calibration, supported by additional practical exercises and systematic testing procedures, may further improve students' learning outcomes and the reliability of the developed systems.

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