Iot-Based Microcontroller Trainer Media: Innovation for Vocational Education Essential Programs

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Abstract: Vocational or technical education is inseparable from the application and advancement of technology, particularly the Internet of Things (IoT), which has brought significant changes to various fields, including vocational education at the Faculty of Engineering, Universitas Negeri Makassar (FT UNM). Vocational education students require interactive learning media to facilitate their understanding of microcontroller fundamentals and IoT applications. The main issue addressed in this study is the absence of learning media based on microcontrollers and IoT applications. This study aims to develop an IoT-based microcontroller trainer media using three main types of microcontrollers: (1) ATmega, (2) Arduino Uno, and (3) NodeMCU. The trainer media is designed to enable students to learn programming steps, hardware integration, and IoT connectivity within a unified platform. The development method employed is Research and Development (R&D), encompassing stages from needs analysis to evaluation. Testing with students revealed that the trainer media effectively enhanced their understanding of microcontrollers and IoT. The implementation and trial results showed that 85% of students could utilize the product and practically and interactively analyze basic IoT concepts. This study demonstrates that the developed trainer media serves as an essential learning tool to support vocational education for students in Electronic Engineering Education.

Keywords: Learning Media, Microcontroller Trainer, Vocational Education

I. Introduction

In the digital era, the Internet of Things (IoT) technology has emerged as a key tool that connects electronic devices to the internet, enabling more efficient communication and data exchange, particularly in vocational learning [1]. The application of this technology is not only prevalent in industries but also increasingly critical in vocational education, particularly in electronic engineering education. Within the learning context, introducing IoT allows vocational education students to understand and describe how IoT devices and microcontrollers communicate autonomously and can be monitored remotely. However, teaching IoT concepts poses challenges, as it requires essential competencies in microcontrollers and strong skills in programming languages.

Students in vocational education programs, particularly those in electronic engineering education, need to master these skills as they are vital assets for their careers in engineering and technology education. To achieve this, practical and interactive learning media are essential, enabling students to directly apply the concepts they learn. Through IoT-based microcontroller trainer media, students can learn to program, connect, and operate IoT systems on a small scale. This approach also helps them develop an understanding of network systems, sensors, and actuators commonly used in IoT applications [2].

The microcontroller trainer media developed in this study utilizes three types of microcontroller chips: ATmega, Arduino Uno, and NodeMCU. Each microcontroller has unique characteristics that support IoT learning with broad coverage, ranging from basic programming to IoT implementation via WiFi connectivity. With this trainer, students are expected to comprehensively understand IoT technology and gain practical experiences aligned with industry demands. This research aims to develop the trainer and evaluate its effectiveness in enhancing students' understanding of microcontroller and IoT concepts.

II. Research Method

This study employs the Research and Development (R&D) methodology, comprising five main stages: needs analysis, product design, development, testing, and evaluation. Below are detailed explanations of each stage:

a. Needs Analysis

The initial stage focuses on analyzing the specific needs of students in learning IoT and microcontrollers. Data were collected through interviews and discussions with lecturers and students from the Electronic Engineering Education program to identify essential competencies, common challenges in understanding IoT concepts, and preferences for hands-on learning media. The results of this analysis served as the foundation for designing and developing relevant and effective microcontroller trainer media tailored to the learning needs.

b. Product Design

The product design stage aims to create an initial design of the trainer media, encompassing both technical and functional aspects. During this stage, a schematic design of the trainer media was created, integrating three primary microcontrollers: ATmega, Arduino Uno, and Node MCU. These microcontrollers were equipped with supporting components, such as sensors, actuators,

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and WiFi modules, to enable basic IoT functionality. A Printed Circuit Board (PCB) layout was designed to optimize component placement and minimize circuit interference using PCB design software.

c. Development

The development stage involves fabricating the physical trainer media based on the finalized design. The steps include:

i. Schematic Design

Completing the electronic circuit schematic, integrating the three microcontrollers with supporting components such as temperature and humidity sensors, actuators, WiFi modules, and LED indicators.

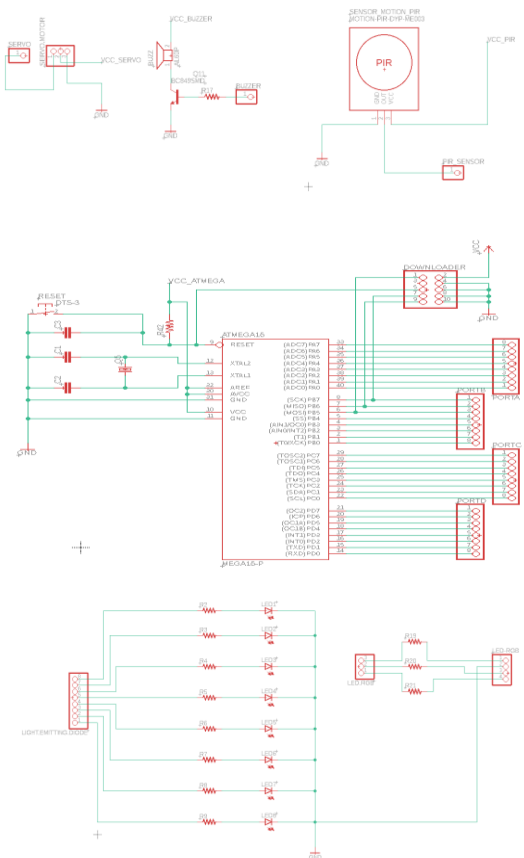

Figure 1. Media Trainer Schematic

ii. PCB Layout

Creating the PCB layout using PCB design software, optimizing component placement and circuit pathways for connectivity, maintenance, and signal integrity.

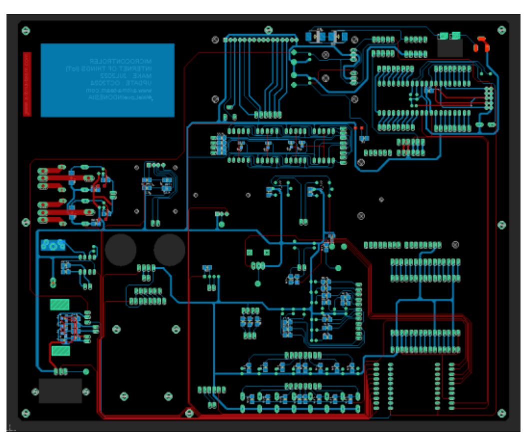

Figure 2. PCB Layout

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iii. PCB Printing and Assembly

Sending the PCB layout for fabrication on fiberglass material with a copper layer. Afterward, components are mounted and soldered onto the completed PCB.

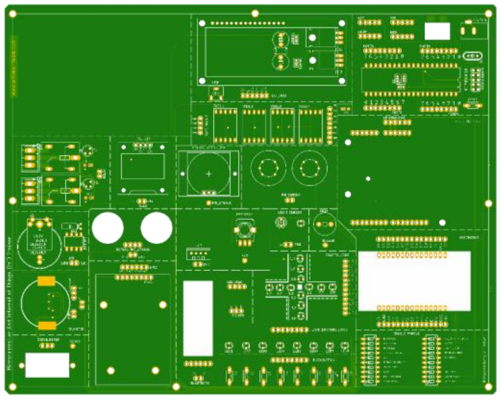

Figure 3. Top View

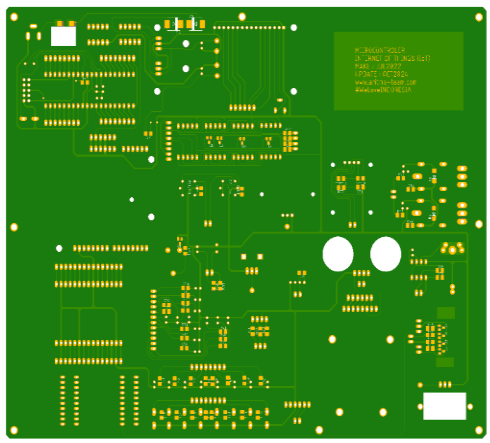

Figure 4. Bottom View

iv. Enclosure Design

Placing the assembled components into a coper box (protective casing made of metal or hard plastic) to shield the circuit from physical damage. The casing was designed for easy access to ports and connectors, such as USB ports and sensor connectors, enabling students to connect external devices conveniently.

Figure 5 - Trainer Media Enclosure

d. Testing

The trainer media underwent functionality testing to ensure all components and features operated as intended. This included: Testing the functionality of each microcontroller module (ATmega, Arduino Uno, and NodeMCU). Testing IoT connectivity to confirm that the NodeMCU module could connect to WiFi networks and transmit data to servers or applications. Verifying the operation of all circuits and sensor modules to ensure cohesive functionality.

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e. Evaluation

The evaluation phase involved providing the trainer media to a group of students for use in a learning session. Afterward, students completed questionnaires to provide feedback on the trainer's effectiveness in improving their understanding of IoT and microcontroller concepts. The feedback was utilized for further refinement of the trainer media before its broader implementation.

Figure 6 - Student Utilization of Trainer Media

This study aims to produce an effective and relevant IoT-based microcontroller trainer media for Electronic Engineering Education students, equipping them with industry-relevant skills.

III. Results and Discussion

The outcomes of developing IoT-based microcontroller trainer media were evaluated to assess its effectiveness as a learning tool for students in the Electronic Engineering Education program. The trainer media comprises three main microcontroller modules—ATmega, Arduino Uno, and NodeMCU each supporting the teaching of foundational concepts and IoT applications. The results from the development and trials are summarized as follows:

f. Media Trainer Design and Construction

The trainer media was successfully designed and constructed according to the specified requirements. The design process included schematic development, PCB layout design, and assembly in a protective coper box. The PCB component layout was optimized to ensure all modules, sensors, and actuators work synergistically and remain easily accessible for students. The coper box provided robust protection for circuits and components, ensuring durability and portability while allowing convenient access to ports and connectors. The design resulted in a trainer media that is structurally sound, portable, and user-friendly.

g. Functionality Testing

Functionality tests were conducted to verify the performance of the three microcontroller modules and supporting components such as sensors and actuators. The results demonstrated that each microcontroller performed as intended:

i. ATmega: Enabled basic microcontroller programming exercises, such as controlling LEDs and reading input from simple sensors. Students practiced fundamental coding in C.
ii. Arduino Uno: Provided a user-friendly programming environment for implementing various basic projects, including temperature and humidity control or motor control applications.
iii. NodeMCU: Acted as the primary connectivity module for IoT applications. Tests showed that NodeMCU successfully connected to WiFi networks and transmitted sensor data to online servers or IoT platforms, allowing students to understand IoT device communication fundamentals.

The results indicated successful integration of all modules, meeting the design specifications. NodeMCU's signal quality and WiFi connectivity stability were sufficient for learning activities.

h. Students Evaluation

A group of students participated in learning sessions using the trainer media. After the sessions, they completed questionnaires to evaluate the trainer's effectiveness in enhancing their understanding.

Table 1 Student Trial Evaluation

Number	Evaluation Aspect	Percentage
1	Improving understanding of microcontroller and IoT basics	85%
2	Supporting comprehension of the connection between theory	78%

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	and practical IoT applications	
3	Increasing engagement and interest in learning	82%

The questionnaire results showed that 85% of students found it easier to grasp basic microcontroller and IoT concepts after using the trainer. Several students noted that the trainer helped them better understand the link between theoretical concepts and practical IoT applications. Additionally, students felt more engaged and interested in learning, as they could directly practice the theories they had studied.

Based on the trial and questionnaire results, the trainer media proved effective in assisting students in understanding the fundamentals of microcontrollers and IoT. The combination of three microcontroller types provided a comprehensive learning experience, from basic programming to IoT implementation. The trainer not only facilitated conceptual understanding but also enhanced students' skills in integrating hardware components for practical applications.

IV. Conclusion

This research successfully developed an IoT-based microcontroller trainer media that effectively supports the learning process for electronic engineering students. By integrating three key microcontrollers—ATmega, Arduino Uno, and NodeMCU—the trainer offers hands-on experiences that simplify the understanding of IoT concepts and their applications in engineering.

The student trials indicated that the trainer enhanced their understanding and interest in IoT learning. A total of 85% of students agreed that the media clarified the connection between IoT theory and practice, making it more effective in strengthening their comprehension. Suggestions such as adding sensor data display features provide valuable input for further improvements, ensuring the trainer better aligns with practical industry needs

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