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Design and Development of a Microcontroller and IoT-Based Learning Trainer for the Sensor and Transducer Practicum Course

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Abstract*—This study aimed to develop an Internet of Things (IoT)-based learning trainer for the Sensor and Transducer Practicum course in the Electronics Engineering Education Study Program at Universitas Negeri Jakarta. The research employed the Research and Development (R&D) method using the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation stages. The developed product is a learning trainer based on Arduino, ESP32, and ESP8266 microcontrollers, integrated with ten sensors and ten actuators, and equipped with practicum worksheets introducing the Blynk application for IoT learning. Data were collected through observation and Likert-scale questionnaires, and the product was validated by instructional design, media, and material experts before being trialed on students. The feasibility results were 93.33% from the instructional design expert, 86.67% from the media expert, and 94.67% from the material expert, all categorized as highly feasible. The one-to-one and small-group user trials obtained 94.67% and 93.78%, respectively, also categorized as highly feasible. These results indicate that the developed trainer is highly feasible for use as a supporting medium for learning and practicum in the Sensor and Transducer Practicum course.

***Index Terms*—ADDIE, Internet of Things, learning media, microcontroller, sensor and transducer.**

I. INTRODUCTION

The Industrial Revolution 4.0 has brought major changes to the world of work and education, and technology adoption in learning has become essential to help students adapt to current demands [1]. One key technology of this era is the Internet of Things (IoT), which enables devices and sensors to connect and share data over the internet. Its application is not limited to industry, since the use of IoT in higher education also positively affects learning effectiveness and student readiness for the digital industry [2], and its integration is considered important for creating an innovative and relevant learning ecosystem [3].

At the Electronics Engineering Education Study Program of Universitas Negeri Jakarta, the Sensor and Transducer Practicum course requires students to understand sensors, transducers, and their implementation on microcontrollers as a foundation for designing applied electronic systems, particularly IoT-based devices. Learning media plays an important role in helping students connect theory with practice [4], yet the available trainers are still limited to a single microcontroller type and have not integrated multiple sensors, transducers, and IoT technology within one learning system.

Several studies have shown that microcontroller-based trainers can improve practicum learning effectiveness. A trainer kit development for ATmega16 microcontroller was reported to increase student engagement in vocational learning [5], while an ESP32-based IoT trainer was developed to support programming and microcontroller courses [6]. Other studies on Arduino-based sensor trainers [7], [8] and Blynk-integrated microcontroller trainer kits [9] also reported positive learning outcomes. However, most of these studies have not optimally integrated IoT technology or still rely on a single microcontroller type.

Based on this gap, this study focuses on designing, developing, and evaluating the feasibility of a learning trainer based on microcontrollers and IoT for the Sensor and Transducer Practicum course. The developed trainer integrates Arduino Uno, ESP32, and ESP8266 microcontrollers with ten sensors and ten actuators, and is equipped with a structured jobsheet that introduces the Blynk application as a basic implementation of IoT.

II. LITERATURE REVIEW

This study applies the Research and Development (R&D) method, which is a series of processes used to create a new product or refine an existing one, acting as a bridge between basic and applied research [10]. The development model used is ADDIE (Analysis, Design, Development, Implementation, Evaluation), a systematic instructional design model developed with a structured sequence of activities to solve learning problems related to appropriate learning resources [11].

Related studies on microcontroller-based learning trainers were reviewed for comparison, as summarized in Table I. While previous trainers have supported sensor and actuator learning, most used a single microcontroller and had not optimally integrated IoT technology, which is the gap addressed by this study.

TABLE I. COMPARISON WITH RELATED RESEARCH

Researcher	Developed Product	Key Difference
Fauzi (2020) [7]	Arduino-based sensor trainer	This study integrates three microcontrollers (Arduino Uno, ESP32, ESP8266)

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Wibowo & Nandika (2022) [9]	Microcontroller trainer for sensor/actuator learning	This study adds a basic IoT implementation introduction
Jisyakirin (2023) [8]	Microcontroller-based sensor/actuator trainer	This study integrates a greater number of sensors and actuators
This study	Microcontroller and IoT-based learning trainer	Combines multiple microcontrollers, sensors, actuators, jobsheet, and Blynk IoT introduction

III. METHOD

This study used the Research and Development (R&D) method with the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation, as illustrated in Fig. 1.

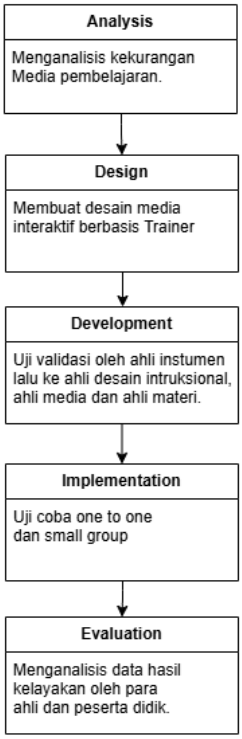

Fig. 1. Research and Development Flow Diagram

In the Analysis stage, the needs and problems of the Sensor and Transducer Practicum learning were identified, showing that available media had not fully supported an integrated understanding of sensors, transducers, microcontrollers, and IoT. In the Design stage, the trainer concept, circuit schematics, block diagrams, and assessment instruments for the instructional design, media, and material experts were developed, resulting in a physical design measuring 40 cm x 60 cm as shown in Fig. 2. In the Development stage, the trainer was physically assembled and programmed using Arduino IDE, followed by validation from the instructional design, media, and material experts. In the Implementation stage, the trainer was trialed on students through one-to-one and small group trials. Finally, in the Evaluation stage, a formative evaluation was carried out to assess the feasibility of the developed media based on expert validation and user trial results.

Fig. 2. 3D Design of the Sensor and Transducer Trainer

Data were collected through observation and Likert-scale questionnaires distributed to one instructional design expert, one media expert, one material expert, and 12 students of the Electronics Engineering Education Study Program (3 students for the one-to-one trial and 9 students for the small group trial). All questionnaires were validated by an instrument expert prior to use. The average score and feasibility percentage were calculated following the formulas of Sugiyono [12], and the results were interpreted using a feasibility criteria scale in which a score of 81–100% is categorized as "highly feasible."

IV. RESULTS AND DISCUSSION

The final product is a learning trainer measuring 40 cm x 60 cm that integrates three microcontrollers (Arduino Uno, ESP32, and ESP8266), ten sensors (ultrasonic, infrared, LDR, temperature/DHT11, inductive proximity, capacitive proximity, optocoupler, RFID, rain, and touch sensors), and ten actuators (LED, servo motor, buzzer, stepper motor, DC motor, LCD 16x2, speaker, DC pump, mini fan, and solenoid), as shown in Fig. 3. The trainer is equipped with a structured jobsheet and a basic introduction to the Blynk application as an IoT implementation example.

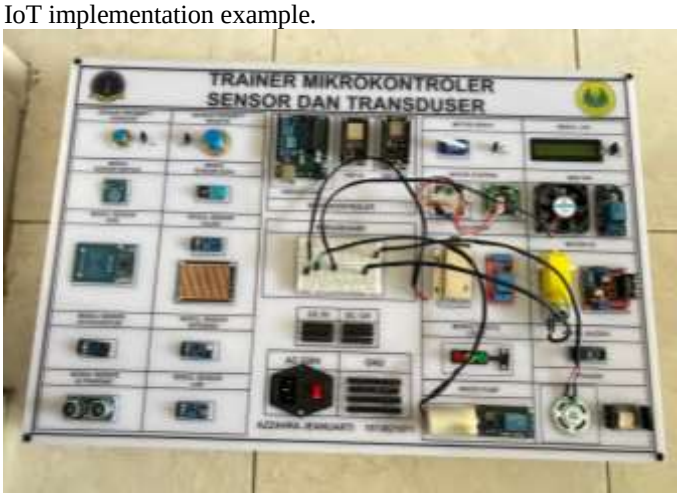

Fig. 3. Final Product of the Sensor and Transducer Trainer

A technical function test confirmed that all sensors, actuators, microcontrollers, and the integrated IoT system operated according to their design, indicating that the trainer was ready to proceed to the feasibility test stage.

A. Expert Validation Results

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TABLE II. EXPERT VALIDATION RESULTS

Validator	Score	Max Score	Percentage (%)	Category
Instructional Design Expert	84	90	93.33	Highly Feasible
Media Expert	65	75	86.67	Highly Feasible
Material Expert	71	75	94.67	Highly Feasible

The instructional design expert rated the trainer's learning objectives, content structure, and jobsheet flow as systematic and supportive of the intended learning outcomes. The media expert rated the trainer's visual design, layout, and ease of use positively, though it received the relatively lowest score among validators; the expert recommended adding a QR code on the trainer for quicker access to the jobsheet. The material expert confirmed that the sensor, transducer, microcontroller, and basic IoT content aligned with the course learning outcomes.

B. User Trial Results

TABLE III. USER TRIAL RESULTS

Trial Stage	Participants	Percentage (%)	Category
One-to-One	3 students	94.67	Highly Feasible
Small Group	9 students	93.78	Highly Feasible

Students responded positively to the trainer, reporting that it was easy to use, had a clear layout, and supported the practicum activities. The slightly lower small-group score compared to the one-to-one score was not significant and is likely due to greater variation in responses as the number of participants increased.

These findings are consistent with previous studies showing that microcontroller-based trainers can effectively support practicum learning [7], [8], [9]. Compared with those studies, this research combines three microcontrollers, a broader set of sensors and actuators, a structured jobsheet, and a basic IoT introduction using Blynk within a single integrated learning system, as summarized in Table I. However, this study is limited to a small-scale trial (one-to-one and small group) and does not measure the trainer's effect on learning outcomes through an experimental pretest–posttest design, which is recommended for future research.

V. CONCLUSION

A microcontroller and IoT-based learning trainer for the Sensor and Transducer Practicum course was successfully developed using the Research and Development (R&D) method with the ADDIE model. The final product integrates Arduino Uno, ESP32, and ESP8266 microcontrollers with ten sensors and ten actuators, and is equipped with a jobsheet introducing the Blynk application for basic IoT implementation. The feasibility test results were 93.33% from the instructional design expert, 86.67% from the media expert, and 94.67% from the material expert, while the one-to-one and small-group user trials obtained 94.67% and 93.78%, respectively — all categorized as highly feasible. These results indicate that the developed trainer is highly feasible for use as a supporting medium for learning and practicum in the Sensor and Transducer Practicum course. Future research is recommended to evaluate the trainer's effect on student learning outcomes through an experimental design and to test it on a larger scale.

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