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IoT Smart Laboratory Trainer Based on Raspberry Pi as Education for Electrical Engineering Students at Telecommunication Laboratory, Surabaya State University

Hikmat Oka[1*], Nur Kholis[2], Nusriningyati[3], Rokhis Rosyidi[4]
[1,2,3,4]Engineering Department, State University of Surabaya, Surabaya
Coresponding author: hikmatkusuma@unesa.ac.id

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ABSTRACT

In order to carry out the process of learning and teaching at the Telecommunications Laboratory in Universitas Negeri Surabaya, efforts to increase student learning efficiency in the field of telecommunications must be preserved, and for that particular reason creating learning media in the form of an IoT-based smart laboratory trainer kit using a Raspberry Pi is expected to increase learning efficiency. The aim is that students can learn to make IoT-based smart laboratory applications with simple sensors and actuators as a simplification in real-world applications. The students will increase their understanding of the material exponentially and will greatly support student competence before entering the workplace. This study used Research and Development (R&D) method by creating a learning media prototype. The steps taken are media design, tool design, software-hardware integration, and the final step is tool validation. The result of this study is an IoT-based smart laboratory trainer kit with excellent validation value as proof that the tool is suitable as a learning medium.

INTRODUCTION

In order to carry out the teaching and learning process in the Telecommunications Laboratory University the State of Surabaya, efforts to increase student learning efficiency in the field of telecommunications must be maintained, and for this reason learning media in the form of an IoT-trainer kit based on Raspberry Pi are expected to increase learning efficiency. The goal is that students can learn to make IoT-based smart laboratory applications with simple sensors and actuators as simplifications in real-world applications. The students will increase their understanding of the material exponentially and will greatly support the competence of students before entering the world of work.

This study uses the Research and Development (R&D) method by making prototypes of learning media. The steps taken are media design, tool design, software-hardware integration, and the final stage is tool validation.

RESEARCH METHOD

An IoT-based smart laboratory prototype is developed for enhancing critical thinking skills in telecommunications competencies among PTE Universitas Negeri Surabaya (UNESA) students using a well-defined model. This model follows a Research and Development (R&D) cycle, which encompasses various essential activities: preliminary investigation, design, realization/construction, test, evaluation, revision, and implementation, as recommended by Plomp (2007).

Additionally, Borg & Gall (Sugiyono, 2010) proposed a 10 (ten) stage research and development method, including stages such as potential and problem identification, data collection, product design, design validation, design revision, product testing, and analysis. However, in this study, seven stages were executed since mass production of the learning media was not required.

The stages involved in this study were potential and problem identification, data collection, product design, design validation, design revision, product testing, analysis, and reporting. The stages involved in this study were potential and problem identification, data collection, product design, design validation, design revision, product testing, analysis, and reporting.

IoT Smart Laboratory

The Raspberry Pi is a compact single-board computer, similar in size to an ATM card, which offers the functionality of a personal computer. It has become particularly advantageous for electrical engineers due to its notable feature of providing 40 GPIO pins, the GPIO pins encompass various features, including UART, SPI, I2C, PWM, interrupts, and power supply options. This extensive set of features makes the Raspberry Pi highly suitable for students pursuing projects in automation systems, data logging and analysis, and IoT applications. Over the past two decades, the Raspberry Pi Foundation has introduced several models of Raspberry Pi. However, for the purpose of this study, the Raspberry Pi Model 3B+ was chosen primarily because of its affordability. This model is equipped with Raspi OS which is an open- source operating system based on Debian Linux, which is compatible with numerous programming languages. In this study, Python 3 was specifically utilized to develop an IoT-based smart laboratory system. The system encompasses three main components: monitoring, data management, and control management.

Learning Media Design

The design of this smart laboratory system essentially comprises three main components: monitoring, data management, and control. The monitoring component involves tracking the temperature, humidity, and air quality. This information is displayed on a 16x2 I2C LCD screen. The attendance records are also displayed on a 16x2 I2C LCD screen, the attendance records are also stored in a database for future reference and record-keeping purposes.

All of these systems can be controlled and monitored through the Telegram application. In order to simplify the wiring process, this study includes a GPIO expansion board and a small breadboard. These additions are aimed at enhancing the versatility of the trainer, allowing it to be utilized for various other applications. It is worth noting that the applications provided by the trainer are merely examples intended for initial learning purposes.

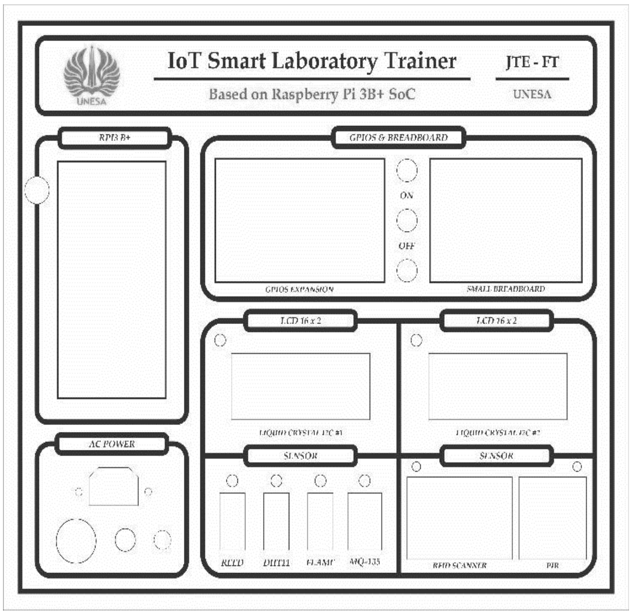

Figure 1. IoT Smart Laboratory Design

The training kit incorporates a 5mm thick acrylic board as the panel for component installation. The design and layout of the components have been optimized to simplify the process of cutting and printing acrylic. The acrylic panels are securely installed in a suitcase with a special holder, ensuring durability and easy accessibility of the training kit.

The IoT Smart Laboratory prototype has been meticulously designed using CorelDRAW, a powerful vector graphics software. CorelDRAW offers a wide range of tools and features that have been utilized to create the visually appealing and precise layout of the acrylic panels for the training kit, the design is shown in Figure 1.

Feasibility of the Learning Media

According to Nieven (2010), the feasibility of learning media is an important factor in determining its suitability for the teaching and learning process. In development research, the quality assessment of a product encompasses three crucial aspects: validity, effectiveness, and practicality. In this particular study, the feasibility of the training kit was assessed solely through the expertise of instructional media experts and regulatory system engineering experts. Validity plays a significant role in evaluating the training kit's suitability for learning purposes. The input and recommendations from experts are vital in refining the learning media. Validity is further divided into three categories: content validity, construct validity, and criterion-related validity.

Content validity refers to the extent to which an instrument accurately measures the intended content or concept. Criterion-related validity involves validating an instrument by comparing it with other valid and reliable measurements through correlation. If the correlation is significant, the instrument is considered to have criterion validity. Construct validity, on the other hand, pertains to the framework of a concept and focuses on whether the measuring instrument accurately captures the meaning of the concept it intends to measure.

RESULTS AND DISCUSSION

Once the design stage is complete, the next step involves creating the prototype of the IoT Smart Laboratory as a training kit. The prototype is constructed using lightweight materials that are readily available in the market. In accordance with Nurseto's (2012) recommendations, the training kit is designed with visual principles in mind, ensuring it is visible, interesting, simple, useful, accurate, legitimate, and structure.

Table 1. Components For Making Training Kit

	Material Name	Qty	Specifications
1	DHT11	1	5V
2	Reed Switch	1	5V
3	Small Breadboard	1	-
4	RPI GPIO Expansion	1	-
5	LCD 16x2	2	5V

The training kit is assembled within a square box measuring 30 cm x 30 cm x 11 cm, with the components arranged neatly inside, as depicted in Figure 2. The required components for building the training kit are as follows: Raspberry Pi Model 3B, a 220 V AC voltage source, six sensors, two LCD I2C 16x2 displays, a small breadboard, and a USB hard drive for the operating system. The power supply requirement for the Raspberry Pi Model 3B+ is a minimum of 5V/2.5A, the system flowchart is shown in Figure 2.

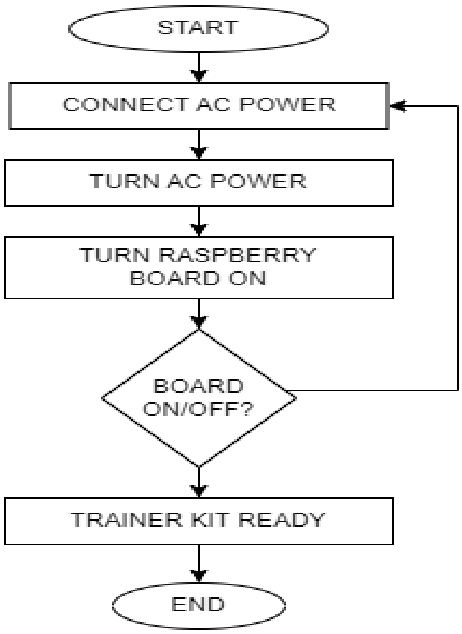

Figure 2. Main system flowchart.

The IoT smart laboratory design consists of three core components: monitoring management, data management, and control management. In this research, I focus in 2 sensor, Light and Temperature sensor.

Monitoring System

The monitoring management component includes the DHT11 sensor for temperature and humidity monitoring, All of these parameters are displayed on the I2C 16x2 LCD screen, specifically on channel #1. Figure 3 illustrates the functioning of the system. In addition to being visually presented on the Liquid Crystal Display (LCD) module, the monitored data obtained from various sensors can also be seamlessly transmitted as real-time notifications through the Telegram messaging platform. To establish a secure and reliable connection between the Raspberry Pi microcomputer and Telegram, the implementation of the BotFather library is required.

The BotFather library, meticulously crafted in the widely adopted Python programming language, serves as a fundamental bridge that facilitates seamless communication and interaction between the Raspberry Pi and the Telegram messaging platform. By leveraging the capabilities of the BotFather library, the system effectively harnesses the power of Telegram to effortlessly transmit informative notifications, updates, and alerts.

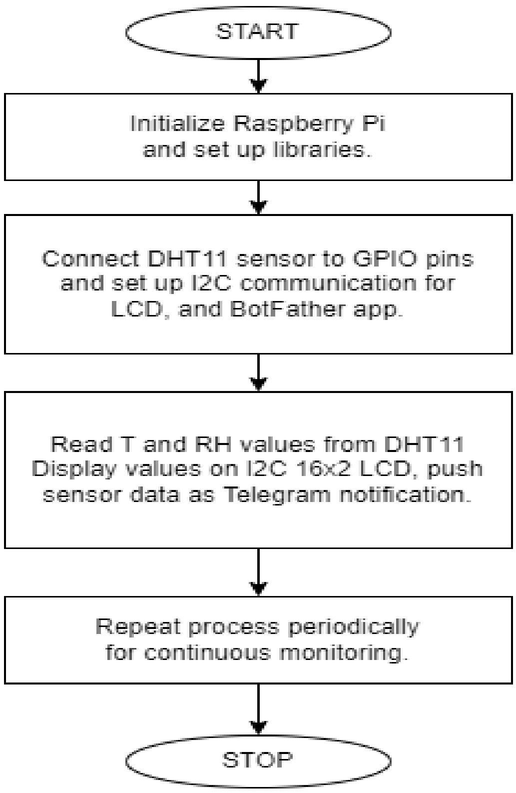

Figure 3. Monitoring system flowchart.

Automation System

In a simplified setup, a Raspberry Pi-based system uses a light sensor and temperature and humidity sensor detection. When a light off sensor is detected, a buzzer will sound an alarm and a notification will be sent via Telegram. This setup provides basic light sensor detection capabilities while offering the flexibility to trigger various responses output. Figure 4 illustrates the system function.

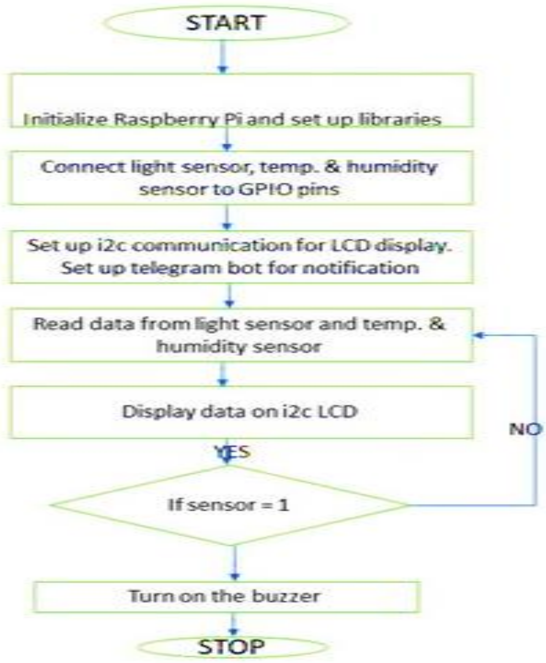

Figure 4. Automation system flowchart.

Final Result

The final result of the IoT Smart Laboratory project is depicted in Figure 6. The picture showcases the fully assembled and functional laboratory setup, consisting of various components and equipment. The Raspberry Pi, acting as the central control unit, is connected to multiple sensors and devices, including the DHT11 sensor for temperature and humidity monitoring.

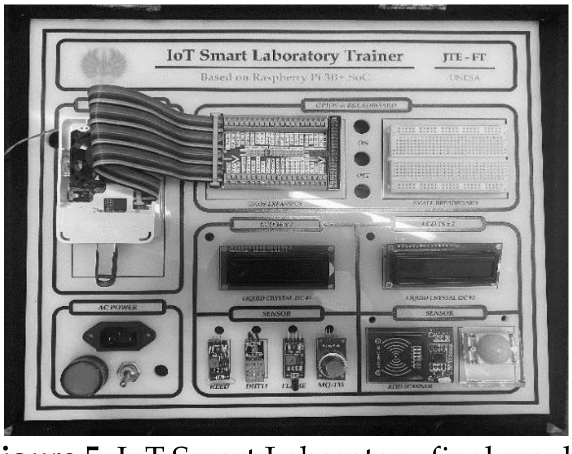

Figure 5. IoT Smart Laboratory final result.

Once the training kit is completed, the next crucial step involves assessing its validity. The validation process entails seeking input from expert validators. These validators consist of three experts: an education and evaluation specialist, an expert in education and learning media, and a specialist in Telecommunications. The validators evaluate the training kit based on specific indicators and aspects, and their ratings are calculated accordingly. The assessment results are then categorized using a Likert scale, developed by Rensis Likert in 1932. This scale is to gauge individuals' perceptions, attitudes, or opinions related to a particular event or social phenomenon. It is a psychometric scale frequently employed in surveys and descriptive survey research. The Likert scale calculations are performed using predetermined formulas [14], the formula to calculate the score is as follows:

$$LS = (\Sigma (Pn * n)) / Tx \quad \ldots(1)$$

Where:
LS: Likert Scale score
Pn: Choice of Likert Scale (e.g., 1, 2, 3, 4, or 5)
n: Number of respondents of the Likert Scale
Tx: Total number of respondents who assessed the survey

This formula calculates the average Likert Scale score based on the choices made by respondents and the number of respondents who selected each choice. The results of the training kit validation were analyzed using a Likert scale which is shown in Table 2 below.

Table 2. Trainer Kit Validation Using Likert Scale

No	***Aspect***	***Indicator***	***Number of Validators who judge***				***Tx Pn***
			1	***2***	***3***	***4***	
1	Training kit's suitability with learning outcomes.	a. The training kit is in accordance with the teaching material presented.				3	12
		b. The use of a training kit helps in understanding the material presented.				3	12
2	Appearance and quality of the training kit.	a. Training kit design.				3	12
		b. The circuit layout in the training kit			1	2	11
		c. The clarity of the drawing				3	12
3	Suitability of the training	a. The suitability of the training kit with the module material			1	2	11

kit with the module	b. Practicum activities with a training kit according to the one in the module	3	12

Table 2 presents the assessment results for various indicators of the IoT Smart Laboratory training kit, result displays the lowest TxPn value for circuit layout and sustainability. This can be attributed to the manual cable interface requiring cable stripping. Future research may explore the use of banana jacks to enhance wiring accessibility. However, there were no issues identified regarding trainer design, compatibility with workbooks, and modules. The IoT Smart Laboratory training kit received a favorable Likert index interpretation, with an average index result of 94.44%. This indicates that the training kit is highly suitable for learning telecommunications. Gavali (2016) emphasized the importance of laboratory demonstration projects in enabling students to apply their theoretical knowledge to real engineering problems [15].

CONCLUSION

The IoT Smart Laboratory prototype has proven to be a remarkable training kit for PTE (Programmable Telecom Environment) students, fostering a substantial enhancement in their telecommunications and programming skills. Its impact on the learning experience has been nothing short of exceptional, with a remarkable Likert index value of 94.44%. This high satisfaction rating is a testament to the system's unparalleled effectiveness as a learning medium Students have not only found the system engaging but also instrumental in bridging the gap between theoretical knowledge and practical application. The hands-on experience offered by the IoT Smart Laboratory has enabled them to grasp complex telecom concepts with greater ease.

The overwhelmingly positive feedback from both students and instructors underscores the IoT Smart Laboratory's vital role in nurturing the next generation of telecom and programming experts. Its proven track record as an effective educational tool is a testament to its design and functionality, making it an invaluable asset in the realm of technology education

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