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Development of an IoT-Based Trainer Kit for Digital Electronics Practicums for Physics Education Students

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Abstract

Background of study: The development of Internet of Things (IoT) technology requires digital electronics learning to be oriented not only toward theoretical understanding but also toward contextual and applicable practical experiences. However, the implementation of Digital Electronics practicums for Physics Education students still faces limitations in integrated practicum media capable of connecting the concepts of logic gates, sensors, microcontrollers, and internet-based data monitoring.

Aims and scope of paper: This research aims to develop and test the feasibility of an IoT-based Trainer Kit to support Digital Electronics course practicums for Physics Education Study Program students. Methods: This study used the research and development method with the ADDIE model, which includes analysis, design, development, implementation, and evaluation. The products were an IoT Trainer Kit and a practicum module. Data were collected through subject-matter and media expert validation questionnaires, student response questionnaires, and an educator response questionnaire. The small-group trial involved 13 Semester IV students organized into four groups, with responses summarized at the group level, while the field trial involved 25 Semester IV students taking the Digital Electronics course and providing individual responses. Data were analyzed descriptively using feasibility percentages.

Results: The Trainer Kit received feasibility scores of 96.94% from subject-matter experts and 93.89% from media experts. The small-group trial, field trial, and educator response scores were 88.89%, 82.72%, and 82.48%, respectively.

Conclusion: The developed IoT-based Trainer Kit was rated very feasible by experts and received positive user responses. These findings support its initial use as a Digital Electronics practicum medium, while its effect on conceptual understanding and learning outcomes remains to be tested experimentally.

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INTRODUCTION

The development of digital technology is encouraging higher education institutions to provide learning experiences that are not only conceptual, but also practical, interactive, and relevant to today's technological needs. One area experiencing rapid development is the Internet of Things (IoT), a technology that allows physical devices to connect to the internet to send, receive, and process data in real time (Ghazy et al., 2025; Wilianto & Kurniawan, 2018). IoT is not only developing in the industrial and public service sectors, but has also become an important part of modern digital systems because it is able to connect objects, data, and users in one technological ecosystem (Mouha, 2021). In the context of physics education, IoT has great potential to support lab-based learning, especially in courses related to digital electronics, microcontrollers, sensors, and control systems (Novera Kristianti, 2019; Tin et al., 2018).

The Digital Electronics course is characterized by requiring students to understand the relationship between theoretical concepts and real-world circuit applications. Concepts such as logic gates, binary systems, sensors, actuators, microcontrollers, and signal processing will be more easily understood if students gain hands-on experience through practical activities. Practical media in the form of a trainer kit is one alternative that can help students observe, assemble, test, and evaluate the working principles of electronic systems directly. Trainer kits can also strengthen students' technical skills by providing practical learning experiences, problem-solving, and concrete system testing (Anwar et al., 2021; Hamid et al., 2020; Hidayat et al., 2022; Uyun & Myori, 2021).

In digital electronics learning, practical media is essential because digital concepts cannot be sufficiently understood through verbal explanations or theoretical presentations. Students need hands-on experience connecting inputs, processes, and outputs in digital circuits. Digital electronics trainers can help students understand the principles of circuit operation, component functions, and the relationship between theory and laboratory practice (Ahmad et al., 2025; Izza & Azhar, 2022). In addition, the development of technology-based learning media is also important to support more interactive physics learning and in line with developments in educational technology (Wardhani, 2021; Yuberti et al., 2023).

However, observations in Digital Electronics learning indicate that practical activities are still not fully supported by integrated media. Available practicals tend to use separate tools and are not equipped with systematic practical guidelines. This condition can make it difficult for students to understand the relationship between digital electronics theory and its application in IoT-based systems. In addition, the need for practical media that integrates digital components, microcontrollers, sensors, actuators, and internet-based monitoring platforms is becoming increasingly important so that students can connect electronic concepts with contemporary technological developments. In this study, this need is demonstrated through the results of observations, interviews, and student questionnaires that emphasize the need for an IoT Trainer Kit and practical modules to support Digital Electronics practical activities.

Several previous studies have developed IoT-based trainer kits and learning media Wahyuni et al. (2022), for example, developing IoT trainer media for learning in Vocational High Schools and showing that the media is valid and practical to use. Sudirman et al. (2022) developed a training kit for a goods sorting system in the Industrial Automation course and obtained high feasibility results. Other research by Jiono et al. (2022) shows that the IoT trainer can be used as a learning medium for remote control subjects. Meanwhile, Wibowo dan Nandika (2022) Developing an IoT-based microcontroller trainer kit using Blynk to support practical activities.

However, most of this research still focuses on the context of vocational education, electrical engineering, or specific control systems. Studies specifically developing IoT Trainer Kits to support Digital Electronics practicums for Physics Education students are still relatively limited. In fact, Physics Education students not only need to understand the working principles of digital circuits but also need practical experience in integrating digital technology into physics learning. Therefore, it is necessary to develop practicum media that are appropriate to the needs of Physics Education students, easy to use, equipped with practicum modules, and able to connect digital electronics concepts with IoT applications.

Based on this background, this study aims to develop an IoT-based Trainer Kit for Digital Electronics course practicums for Physics Education students. This study specifically tests the product's feasibility based on assessments by subject matter experts, media experts, student responses, and educator responses. The developed product is expected to be a practicum medium that supports Digital Electronics learning in a more concrete, interactive, and relevant manner to technological developments.

METHOD

Research Design

This research used a research and development (R&D) method. The ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation, was chosen because it offers systematic steps for developing learning products, from needs analysis to product feasibility evaluation (Saregar, 2017; Sugiyono, 2020).

Participant

Participants consisted of three subject-matter experts, three media experts, the lecturer teaching Digital Electronics, and Semester IV Physics Education students at UIN Raden Intan Lampung. The subject-matter experts assessed content quality, learning objectives, and instructional quality, while the media experts assessed technical quality, appearance, ease of use, and instructional quality. The preliminary small-group trial involved 13 students organized into four groups, and the response results were tabulated at the group level. The subsequent field trial involved 25 students who completed practicum activities in four groups of six to seven students; their questionnaire responses were tabulated individually. All student participants were enrolled in the Digital Electronics course. Participant-level information on prior experience with microcontrollers, IoT systems, and Digital Electronics laboratory work was unavailable for analysis; therefore, the response data were not stratified by prior experience.

Population and Sampling Methods

The study population comprised Physics Education students taking the Digital Electronics course. Purposive sampling was used because the participants were directly relevant to the intended use of the IoT Trainer Kit. Product testing was conducted sequentially. The small-group trial involved 13 Semester IV students working in four groups and was used to identify initial usability and feasibility issues; the reported small-group data consisted of four group-level response records. The field trial involved 25 Semester IV students organized into four practicum groups of six to seven students, while the questionnaire data were recorded for the 25 individual participants. Because participant-level information on prior microcontroller, IoT, and laboratory experience was unavailable for analysis, the findings should be interpreted as aggregate user-response evidence rather than comparisons among experience levels.

Instrument

The research instruments consisted of a validation questionnaire and a response questionnaire. The material expert validation questionnaire covered aspects of content quality, objectives, and instructional quality. The media expert validation questionnaire covered aspects of technical quality and instructional quality. The student response questionnaire covered aspects of technical quality, content quality, objectives, and instructional quality. The assessment scale used a five-level Likert scale: strongly agree, agree, undecided, disagree, and strongly disagree (Ernawati, 2017).

Procedures and Time Frame

During the Analysis stage, the researchers conducted learning observations, reviewed the Digital Electronics practicum requirements, conducted interviews, and examined student needs to identify limitations in existing tools and practicum guidance. The output was a set of product requirements: an integrated trainer connecting digital inputs, microcontroller processing, local outputs, and internet-based monitoring, accompanied by a structured practicum module. During the Design stage, the researchers prepared the input-process-output-power architecture, selected the hardware and software components, designed the component layout and wiring scheme, outlined the practicum scenarios, and drafted the validation and response instruments. The output was a product specification, system flow, prototype layout, module outline, and assessment instruments. During the Development stage, the ESP8266/Wemos D1 Mini, DHT11 sensor, push-button switch, I2C LCD, LED, breadboard, adapter, Arduino IDE program, and ThingsBoard configuration were integrated into a functional prototype, and the practicum module was drafted. Functional testing and expert validation were then conducted. The revision process involved reviewing the feedback, grouping it into hardware, software, and module-related points, applying the required changes, and checking the prototype and module again before implementation.

During the Implementation stage, the validated prototype and practicum module were used first in a small-group trial and subsequently in the field trial during Digital Electronics practicum activities. Students completed the prepared scenarios and provided responses through the questionnaire, while the course lecturer completed the educator response questionnaire. During the Evaluation stage, formative evaluation occurred throughout analysis, design, development, and implementation, while the final evaluation synthesized expert validation scores, student and educator response scores, and qualitative suggestions. Where revisions were required, the relevant hardware, software guidance, or module section was adjusted and checked before the product was finalized (Syathroh & Rizkiani, 2023).

Analysis Plan

Data were analyzed using quantitative descriptive techniques (Sofwatillah et al., 2024). The score obtained from each questionnaire was divided by the maximum possible score and converted into a percentage using the following formula:

$$\text{Feasibility percentage } = \frac{\text{obtained score}}{m\text{aximum possible score}} \times 100\%$$

Table 1. Feasibility Criteria and Percentage Ranges

Percentage range	Feasibility category
80% < P <= 100%	Very Feasible
60% < P <= 80%	Feasible
40% < P <= 60%	Fairly Feasible
20% < P <= 40%	Less Feasible
0% < P <= 20%	Not Feasible

The percentages were interpreted using the five feasibility categories presented in Table 1. For the small-group trial, 13 students worked in four groups and the questionnaire results were summarized as four group-level records. For the field trial, questionnaires were tabulated for 25 individual students, although the practicum activities were conducted in four groups. Qualitative comments, criticisms, and suggestions from the validators and users were also examined and used as the basis for product revision (Rahmawati et al., 2023).

Scope and Limitations

This research focuses on the development and feasibility testing of an IoT-based Trainer Kit for Digital Electronics practicums. This study has not yet tested the product's effectiveness in improving student learning outcomes through a pretest-posttest experimental design. Therefore, the findings of this study are more appropriately interpreted as evidence of initial feasibility and practicality, rather than as evidence of causal effectiveness in improving learning achievement.

RESULTS AND DISCUSSION

Results

The products developed in this research were an IoT-based Trainer Kit and a practicum module. The final prototype was packaged in a labeled transparent plastic box measuring approximately 20 cm x 16 cm x 5 cm and organized around four functional blocks: power supply, input, processing/connectivity, and output. The input block consists of a DHT11 temperature-humidity sensor and a push-button switch. The processing and connectivity block uses an ESP8266-based NodeMCU/Wemos D1 Mini programmed through the Arduino IDE to read inputs, execute digital logic, control outputs, and transmit data through Wi-Fi. The output block consists of an LED and an I2C LCD, while ThingsBoard provides internet-based data monitoring. The practicum module contains a cover, foreword, practicum objectives, preparation guidance, operating instructions, job sheets, and a glossary. Its four job sheets address basic logic gates using ESP8266, LED blinking, LED control through a web server, and temperature-humidity monitoring through ThingsBoard. Figure 1 presents the system architecture, Figure 2 documents the final product and its storage box, and Figure 3 shows the ThingsBoard interface and practicum module cover.

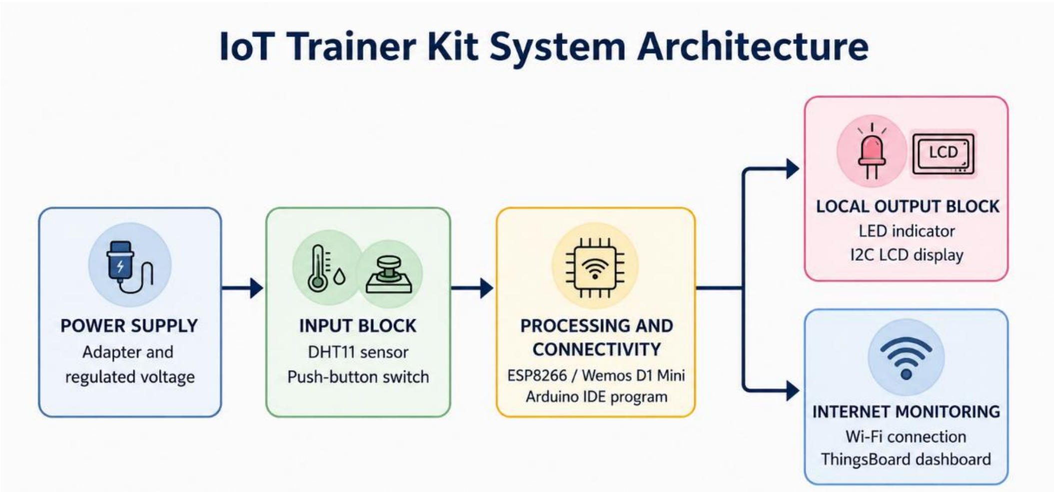
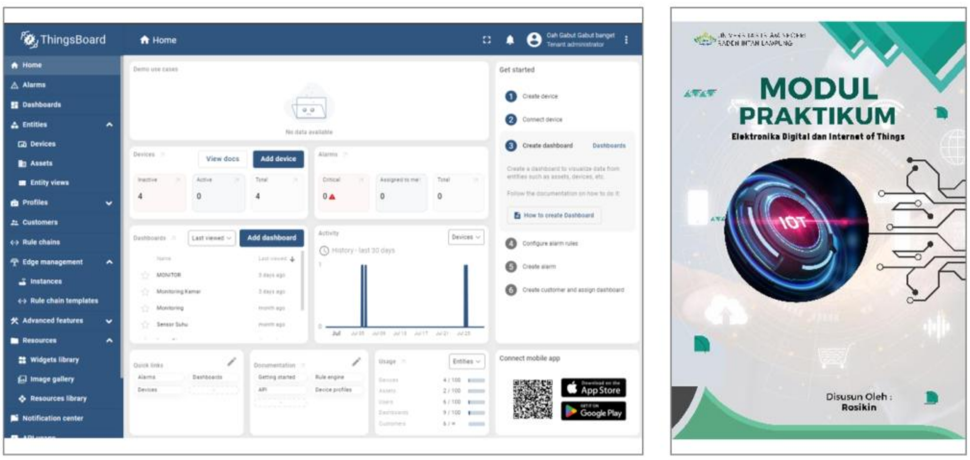


Figure 1. Block Diagram and Data Flow of the IoT-Based Trainer Kit
Source: Redrawn from the research product design.

(a) Trainer Kit used during the Digital Electronics practicum (b) Labeled storage box for Trainer Kit components

Figure 2. Research Documentation of the IoT Trainer Kit and Its Labeled Storage Box
Source: Research documentation (2024).



(a) ThingsBoard dashboard used for IoT monitoring (b) Practicum module cover

Figure 3. ThingsBoard Dashboard and Practicum Module Documentation
Source: Research documentation (2024).

Table 2. Main Components of IoT-Based Trainer Kit

Component	Function
ESP8266 / Wemos D1 Mini	Microcontroller to process data and connect devices to the internet network
DHT11 Sensor	Reading temperature and humidity data
Push Button Switch	Provides logic input to the circuit
LED	Displays visual indicators of digital processes
I2C LCD	Display data or information from the system
Arduino IDE	Writing and uploading programs to the microcontroller
ThingsBoard	Monitoring sensor data through IoT platforms
Practical module	Provides guidance, work steps, and practical job sheets

Before the user trials, the product was evaluated by subject-matter and media experts. The subject-matter expert validation score was 96.94%, and the media expert validation score was 93.89%; both scores were classified as Very Feasible according to the criteria in Table 1.

Table 3. Expert Validation Results

Validator	Percentage	Category
Subject Matter Expert	96.94%	Very Feasible
Media Expert	93.89%	Very Feasible

After expert validation and the corresponding product revisions, the product was evaluated through a small-group trial and a field trial. The small-group response score of 88.89% was calculated from four group-level response records representing 13 students. The field-trial response score of 82.72% was calculated from the individual questionnaires of 25 students, and the educator response score was 82.48%. According to Table 1, all three scores were classified as Very Feasible.

Table 4. Trial Results and User Responses

Types of Assessment	Percentage	Category
Small group trials	88.89%	Very Feasible
Field trials	82.72%	Very Feasible
Educator response	82.48%	Very Feasible

The practicum scenarios enabled users to operate the Trainer Kit for basic logic-gate activities, LED control, web-server operation, and temperature and humidity monitoring through ThingsBoard. The module provided step-by-step guidance for preparing the equipment, uploading programs, conducting observations, and recording results. The reported scores represent feasibility and user-response evidence; they do not constitute direct evidence of learning gains.

Discussion

The results of the study indicate that the developed IoT-based Trainer Kit meets the criteria of being highly feasible based on assessments by subject matter experts, media experts, students, and educators. The high validation score from subject matter experts indicates that the product content, learning objectives, and practicum material structure are aligned with the needs of Digital Electronics learning. This is important because practicum media must not only be technically engaging but also align with the learning outcomes of the course.

The media expert validation score indicates a favorable assessment of the Trainer Kit's technical quality, appearance, ease of use, and instructional suitability. The integration of the ESP8266/Wemos D1 Mini, DHT11 sensor, I2C LCD, LED, Arduino IDE, and ThingsBoard was designed to allow practicum users to trace the relationship among digital inputs, microcontroller processing, local outputs, and internet-based monitoring. This interpretation concerns the product's design and feasibility; it does not demonstrate that students' conceptual understanding improved.

The small-group and field-trial response scores indicate that students perceived the product positively and regarded it as supportive of the practicum activities. The response data can be interpreted as evidence of initial usability and acceptance. However, conceptual understanding, engagement, and learning achievement were not measured using dedicated instruments or an experimental design. Therefore, the findings should not be interpreted as demonstrating improvement in those outcomes.

This finding is in line with previous research showing that trainer kits can support practice-based learning activities. Anwar et al. (2021) states that the trainer kit can be used as a learning medium for electricity and electronics to help students understand the system through direct experience. Hamid et al. (2020) also emphasized that the development of electrical circuit kits can support basic electrical and electronics practices. In the context of IoT, Wahyuni et al. (2022) shows that the IoT trainer media is valid and practical to use in learning, while Jiono et al. (2022) shows that IoT trainer can be a suitable learning medium for remote control topics.

The novelty of this research lies in the development of an IoT Trainer Kit specifically structured for Digital Electronics practicums in a Physics Education program. The product combines input, processing, local output, and internet-monitoring functions with a practicum module containing user guidance, worksheets, observation tables, and structured scenarios. This combination distinguishes the product from a stand-alone demonstration device and provides a guided medium for individual or group practicum use.

Implications

The practical implication of this research is that the developed Trainer Kit represents a feasible option for organizing Digital Electronics practicums that connect logic gates, microcontrollers, sensors, local displays, and internet-based data monitoring. The product may assist lecturers in presenting the relationships among input, processing, and output in an observable system. For students, it provides access to guided practice with components and platforms relevant to introductory IoT applications. These implications concern the product's intended use and perceived feasibility rather than experimentally verified improvements in learning.

Research Contribution

The contribution of this research lies in providing a practical medium that integrates the concepts of Digital Electronics and IoT in the context of Physics Education. The developed product can serve as a starting point for the development of other practical media based on microcontrollers, sensors, and digital platforms. This research also provides practical contributions to study programs in providing learning tools that support technology-based learning.

Limitations

This study has several limitations. First, product testing was limited to one study program and one course. Second, the study did not use a pretest-posttest or controlled experimental design to examine effects on conceptual understanding or learning outcomes. Third, the IoT components were limited to a DHT11 sensor, LED, I2C LCD, ESP8266-based boards, and ThingsBoard. Fourth, participant-level information on prior experience with microcontrollers, IoT systems, and Digital Electronics laboratory work was unavailable for analysis, so response patterns could not be compared across experience levels. Fifth, the small-group results were summarized at the group level rather than as individual participant responses. Sixth, the product documentation and troubleshooting guidance require further refinement for novice users.

Suggestions

Further research is recommended to test the effectiveness of the Trainer Kit through experimental design, for example by comparing student learning outcomes before and after product use. Further development could also include a wider range of sensors and actuators, such as light sensors, proximity sensors, relays, servo motors, or integration with mobile applications. The practical module should also be expanded with problem-based project scenarios to enable students to develop critical thinking, problem-solving, and technological creativity.

CONCLUSION

This research produced an IoT-based Trainer Kit and a practical module to support Digital Electronics learning for Physics Education Study Program students. The product was developed using the ADDIE model which includes the stages of analysis, design, development, implementation, and evaluation. The validation results showed that the Trainer Kit obtained a percentage of 96.94% from material experts and 93.89% from media experts, both of which are in the very feasible category. The results of small group trials obtained a score of 88.89%, field trials obtained a score of

82.72%, and educator responses obtained a score of 82.48%, all of which are in the very feasible category.
Based on the expert validation and user-response data, the IoT-based Trainer Kit and practicum module were classified as Very Feasible for initial use in Digital Electronics practicums. The evidence supports product feasibility and acceptance but does not establish improvements in students' conceptual understanding, engagement, or learning outcomes. Further research should use a pretest-posttest or controlled experimental design, record participants' prior technical experience, examine a broader range of IoT components, and refine the practicum module with more extensive operating and troubleshooting guidance.

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AUTHOR CONTRIBUTION STATEMENT

RS led the study design, product development, data collection and analysis, and manuscript drafting. YB supervised the study and refined the methodology and discussion. SL supervised product development, reviewed the instruments, and revised the manuscript.

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