

Development of IoT Learning Media for Hybrid Learning Using Wokwi Simulation

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Abstract - *The rapid development of Internet of Things (IoT) technology requires learning media that are able to support practical competencies in flexible learning environments. However, IoT learning implementation in hybrid learning faces major challenges related to limited laboratory facilities and hardware availability. This study aims to develop IoT learning media based on hybrid learning using Wokwi Simulation as a virtual laboratory solution. The research employed a Research and Development (R&D) approach using the 4D development model, consisting of define, design, develop, and disseminate stages. The feasibility of the developed media was evaluated through expert validation and practicality testing. Validation involved three subject matter experts and three media experts, analyzed using Aiken's V coefficient. The results showed that the learning media achieved high validity, with an average Aiken's V value of 0.846 from material experts and 0.929 from media experts. Practicality testing conducted with 15 students resulted in a practicality level of 91.33%, categorized as very practical. These findings indicate that the developed IoT learning media is valid, practical, and suitable for supporting hybrid learning. The integration of Wokwi Simulation provides flexible access, reduces dependency on physical hardware, and enhances students' learning experiences in IoT practical activities.*

Keywords— IoT, Hybrid Learning, Learning Media, Wokwi Simulation, Virtual Laboratory.

I. INTRODUCTION

The rapid advancement of technology in the era of the Fourth Industrial Revolution has positioned the Internet of Things (IoT) as a core competency that must be mastered by students in the fields of technology and informatics [4], [12]. The integration of intelligent devices with internet-based systems has become a fundamental requirement in modern industrial environments, particularly in automation, smart manufacturing, and digital services [6]. Consequently, vocational and higher education institutions are expected to equip learners not only with theoretical knowledge but also with practical IoT implementation skills that align with current industrial demands [16].

In parallel, the education sector has experienced a significant transformation through the adoption of hybrid learning models that combine face-to-face instruction with online learning activities [10], [14]. Hybrid learning has

emerged as a post-pandemic educational standard that supports flexible access, learner autonomy, and continuity of instruction [21]. However, the implementation of IoT practical learning within hybrid learning environments introduces substantial challenges, particularly those related to the availability, cost, and accessibility of physical laboratory infrastructure [22].

One of the main obstacles in IoT education is the heavy dependency on hardware components such as microcontrollers, sensors, and actuators, which are often limited in quantity and prone to technical damage when used by novice learners [16]. These limitations restrict students' opportunities to conduct repeated hands-on experiments and independent exploration. In addition, students participating in hybrid learning frequently encounter difficulties when practicing IoT concepts at home due to the lack of adequate laboratory equipment. This condition creates a gap between conceptual understanding delivered through online instruction and the acquisition of practical competencies required in real-world applications [13].

To overcome these challenges, alternative learning media that can simulate real IoT environments without relying on physical hardware are increasingly required. Previous studies emphasize that learning media must meet rigorous validity standards to ensure content accuracy and instructional relevance [1], [11]. Furthermore, the effectiveness of educational products is strongly influenced by their practicality, particularly their ease of use and applicability in real instructional settings [2], [25]. Well-designed learning media should therefore support both pedagogical objectives and user experience, especially in technology-based learning contexts [20].

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Virtual simulation platforms offer a promising solution to address these limitations. Wokwi Simulation is a web-based electronic simulator that allows users to design circuits and execute microcontroller programs virtually without requiring hardware installation or complex software configurations [8], [9]. The cloud-based nature of Wokwi enables learners to access IoT practical activities anytime and anywhere, which aligns well with the flexibility demanded by hybrid learning environments [22]. Moreover, simulation-based learning environments allow students to experiment freely, identify errors, and refine their understanding without the risk of damaging expensive physical components [5], [15].

Several studies have highlighted the importance of instructional design and systematic development in technology-enhanced learning media [17], [23]. However, many existing simulation-based learning tools have not been empirically evaluated in terms of both validity and practicality, particularly in the context of IoT education [24]. Therefore, there remains a need for the development of structured IoT learning media that integrates virtual simulation platforms within a hybrid learning framework and is supported by rigorous evaluation methods [3], [7], [18].

Based on these considerations, this study aims to develop IoT learning media using Wokwi Simulation to support hybrid learning. The developed media is evaluated through expert validation using Aiken's V coefficient and practicality testing involving students as end users [11], [19]. The results of this study are expected to provide an effective and flexible alternative to physical laboratory-based IoT learning while maintaining instructional quality and relevance to vocational and higher education contexts.

II. RESEARCH METHOD

This study employed a Research and Development (R&D) approach aimed at producing and evaluating IoT learning media to support hybrid learning. The development process adopted the 4D model proposed by Thiagarajan, which consists of four main stages: Define, Design, Develop, and Disseminate [3], [7]. The 4D model was selected because it provides a systematic framework for developing instructional media while ensuring product feasibility through validation and testing stages.

A. Research Design

The overall research design follows the R&D paradigm, focusing on the development of a learning product rather than hypothesis testing. The stages of the 4D model implemented in this study are summarized in Table 1.

Table 1. Stages of the 4D Development Model

Stage	Description
Define	Analysis of curriculum requirements, learning objectives, and student characteristics related to IoT competencies
Design	Design of learning media structure, learning scenarios, and IoT circuit simulations using Wokwi
Develop	Development of the learning media, expert validation, revisions, and practicality testing
Disseminate	Limited dissemination of the finalized learning media through online platforms to support hybrid learning

The workflow of the research method based on the 4D model is illustrated in Fig. 1.

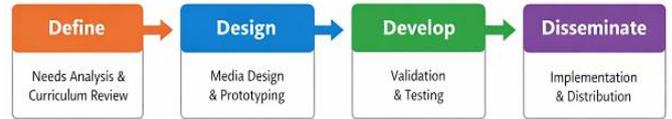


Fig. 1. Research workflow using the 4D development model

B. Development Procedures

1. Define Stage

The define stage was conducted to identify instructional needs and learning constraints. This stage involved curriculum analysis, identification of IoT learning outcomes, and analysis of students' characteristics and learning environments [17], [19]. The results of this stage indicated the need for learning media that could provide practical IoT experiences without relying heavily on physical laboratory equipment, particularly in hybrid learning settings.

2. Design Stage

During the design stage, the structure and content of the IoT learning media were planned. This included the selection of learning materials, preparation of learning scenarios, and the design of IoT circuit simulations using the Wokwi platform. The design process emphasized usability, clarity of instructions, and alignment with learning objectives. The output of this stage was a prototype of the IoT learning media that integrated virtual simulation as a substitute for physical hardware.

3. Develop Stage

The develop stage focused on producing the final version of the learning media through expert validation and testing. Validation was conducted to ensure the accuracy of content, technical quality, and instructional suitability of the media [1], [11]. The validated prototype was revised based on experts' feedback before being tested for practicality by students as end users [18].

4. Disseminate Stage

The disseminate stage involved the implementation and limited distribution of the finalized learning media. The product was made accessible through online platforms to allow students to independently conduct IoT practice activities as part of hybrid learning. This stage aimed to evaluate the readiness of the media for broader application in real learning environments [20].

C. Research Instruments

Three types of research instruments were used in this study:

1. Validation Instruments

Validation instruments were in the form of questionnaires used by subject matter experts and media experts to evaluate content accuracy, instructional design, interface quality, and technical functionality. The validation results were analyzed using Aiken's V coefficient to determine the level of validity of each assessment item [11].

2. Practicality Instrument

The practicality instrument consisted of a questionnaire distributed to students to assess the ease of use,

efficiency, attractiveness, and usefulness of the learning media. Practicality assessment aimed to measure how well the media could be implemented in real learning situations [2], [25].

3. Observation and Documentation

Observation and Documentation were used to support quantitative findings by capturing students' interaction with the learning media and recording implementation conditions during the trial phase.

D. Data Analysis Techniques

Data analysis in this study employed descriptive quantitative techniques. The validity of the learning media was measured using Aiken's V coefficient, which is calculated using the following formulation:

$$V = \frac{\Sigma_s}{n(c - l_o)}$$

where:

$$s = r - l_o$$

r is the score given by the rater,

l_o is the lowest score,

c is the highest score, and

n is the number of raters.

The validity criteria were determined based on the value of V, where values greater than 0.8 indicate high validity [1], [11]. Practicality data were analyzed by converting the total score obtained from student responses into percentage values. The practicality level was then categorized according to established criteria, where higher percentages indicate better practicality [2], [25].

III. RESULTS AND DISCUSSION

This section presents the results of expert validation and practicality testing of the developed IoT learning media, followed by a discussion of the findings in relation to hybrid learning implementation.

A. Results of Define and Design Stages

The initial stages of the 4D development model, namely Define and Design, produced important findings that guided the development of the IoT learning media. These stages focused on identifying instructional needs and translating them into a structured media design suitable for hybrid learning environments.

1) Define Stage Results

The define stage aimed to analyze learning requirements and constraints related to IoT instruction. The analysis was conducted through curriculum review, identification of learning objectives, and examination of students' learning conditions. The results of this stage revealed that IoT learning activities heavily depend on physical laboratory facilities, including microcontrollers, sensors, and actuators, which are limited in availability and vulnerable to damage when used intensively by novice learners.

Furthermore, the analysis indicated that students experienced difficulties in conducting IoT practical activities outside the laboratory, particularly during online learning sessions in hybrid learning settings. These conditions created a gap between theoretical instruction and practical skill acquisition. As a result, there was a clear need for learning

media that could provide practical IoT experiences without relying on physical hardware. The findings of the define stage served as the foundation for selecting a virtual simulation-based approach as an alternative solution to these limitations.

2) Design Stage Results

Based on the findings of the define stage, the design stage focused on translating instructional needs into a concrete learning media design. At this stage, the structure of the IoT learning media was developed, including the organization of learning materials, practical task scenarios, and assessment activities. The design emphasized alignment between learning objectives, learning content, and practical activities to ensure instructional coherence.

In addition, the design stage resulted in the development of IoT practical task scenarios using Wokwi Simulation. These tasks were designed to simulate real IoT systems, including microcontroller programming, input-output control, and cloud-based connectivity. The use of Wokwi allowed the media to support interactive experimentation and immediate feedback, which are essential components in practical learning.

The output of the design stage was a prototype of IoT learning media that integrated simulation-based practice within a hybrid learning framework. This prototype served as the basis for further development and evaluation during the develop stage, including expert validation and practicality testing.

B. Expert Validation Results

The development stage began with expert validation to ensure the feasibility of the IoT learning media in terms of content accuracy and technical quality. Validation was conducted by three subject matter experts and three media experts using instruments analyzed with Aiken's V coefficient. The summary of expert validation results is presented in Table 2.

Table 2. Summary of Expert Validation Results

Expert Group	Average Aiken's V	Category	Validity Criteria
Material Experts (3)	0.846	High	V > 0.8
Media Experts (3)	0.929	High	V > 0.8

As shown in Table II, the validation conducted by material experts resulted in an average Aiken's V value of 0.846. According to the validity criteria proposed by Utami et al., values greater than 0.8 indicate a high level of validity [1]. This result demonstrates that the IoT learning content is aligned with learning objectives, curriculum requirements, and industry-related competencies.

Meanwhile, validation by media experts yielded an even higher average Aiken's V value of 0.929. This finding indicates that the developed learning media has excellent technical quality, including interface design, system functionality, and integration of Wokwi Simulation. The high validity score confirms that the media is technically reliable and suitable for use in hybrid learning environments. The comparison of validity results between material and media experts is illustrated in Fig. 2.

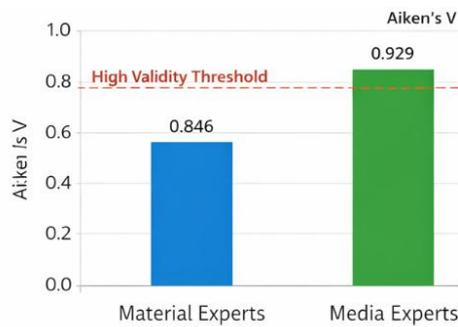


Fig. 2. Expert validation results based on Aiken's V coefficient

The high validation scores reflect the effectiveness of the 4D development process in producing structured and well-evaluated instructional media. The incorporation of expert feedback during the develop stage contributed significantly to improving both content quality and system usability.

C. Practicality Test Results

After being declared valid, the IoT learning media was tested for practicality by involving 15 students as end users. The practicality test aimed to evaluate the ease of use, efficiency, attractiveness, and usefulness of the learning media in supporting hybrid learning activities. The results of the practicality assessment are summarized in Table 3.

Table 3. Summary of Practicality Test Results

Assessment Aspect	Total Score
Ease of Use	285
Learning Efficiency	270
Attractiveness	275
Content Clarity	270
Overall Usefulness	270
Total Score	1370

Based on the data in Table III, the total score obtained from the practicality test was 1370. When converted into a percentage, the practicality level reached 91.33%. According to the practicality criteria proposed by Purwanto, a percentage above 90% falls into the "Very Practical" category [2], [25]. This result indicates that students experienced minimal difficulty in using the learning media and were able to effectively engage with IoT practical activities through Wokwi Simulation.

The distribution of practicality assessment results is illustrated in Fig. 3.

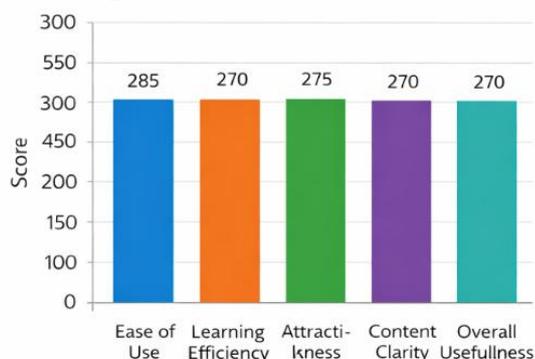


Fig. 3. Practicality test results of the IoT learning media

To further illustrate the implementation of the developed learning media, an example of an IoT practical task using Wokwi Simulation is presented in Fig. 4. This task represents a typical learning activity designed to support students in understanding the integration between microcontroller programming, input-output control, and cloud-based IoT platforms within a hybrid learning environment.

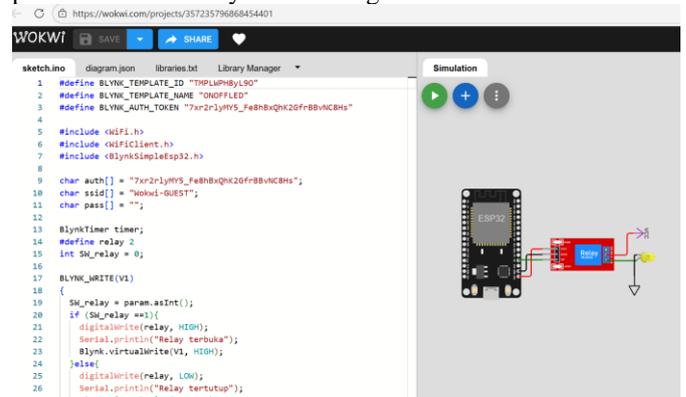


Fig. 4. Example of IoT practical task using Wokwi Simulation

As shown in Fig. 4, the practical task utilizes an ESP32 microcontroller simulated in Wokwi, integrated with a relay module and controlled via the Blynk IoT platform. Students are required to upload program code, configure virtual hardware connections, and test the system logic in real time through the simulation interface. This activity enables learners to practice fundamental IoT concepts such as device connectivity, digital input-output control, and remote system monitoring without relying on physical hardware.

The use of Wokwi Simulation allows students to safely explore circuit design and programming logic, including trial-and-error processes, without the risk of damaging electronic components. This feature significantly enhances students' confidence and engagement, particularly for beginners who are unfamiliar with microcontroller-based systems. In the context of hybrid learning, such simulation-based tasks provide flexible access to practical learning experiences that can be conducted anytime and anywhere.

Furthermore, this task demonstrates how the developed learning media bridges the gap between theoretical instruction and practical application. By integrating virtual simulation with cloud-based IoT services, the learning media supports independent experimentation and reinforces problem-solving skills. This finding supports the high practicality score obtained in the study, as students can effectively complete IoT practical activities despite limitations in laboratory infrastructure.

IV. DISCUSSION

The results of expert validation and practicality testing demonstrate that the developed IoT learning media meets high standards of feasibility and usability. The high validity scores obtained from both material and media experts confirm that the learning content is accurate and the technical implementation is reliable. These findings are consistent with previous studies emphasizing the importance of rigorous validation in the development of educational media [1], [11].

Furthermore, the high practicality score indicates that the learning media can be easily implemented in real learning

situations. The cloud-based nature of Wokwi Simulation allows students to conduct IoT experiments without being constrained by time, location, or hardware availability. This flexibility is particularly beneficial in hybrid learning contexts, where students alternate between face-to-face and online learning modes [10], [14], [21].

The integration of Wokwi Simulation also enables learners to experiment freely without the risk of damaging physical components, which is a common limitation in traditional IoT laboratories [16]. This feature supports exploratory learning and increases students' confidence in practicing IoT concepts independently. In addition, the simulation environment provides real-time feedback, which enhances conceptual understanding and reinforces problem-solving skills.

Overall, the findings indicate that the developed IoT learning media is not only technically valid but also highly practical for supporting hybrid learning. By reducing dependency on physical laboratory infrastructure, the media offers a cost-effective and scalable alternative for IoT education while maintaining instructional quality. These results support the argument that simulation-based learning media can play a critical role in addressing resource limitations in vocational and higher education institutions [22], [24].

V. CONCLUSIONS

Based on the results of the study and the discussion presented, it can be concluded that the development of IoT learning media for hybrid learning using Wokwi Simulation has successfully met the required feasibility criteria for instructional use. The development process using the 4D model resulted in learning media that is systematically designed and aligned with both instructional objectives and technological requirements in IoT education.

The expert validation results indicate that the developed media has a high level of validity. The average Aiken's V value obtained from material experts was 0.846, while validation by media experts reached 0.929. These values, which exceed the validity threshold of $V > 0.8$, confirm that the learning content is accurate and the technical implementation is reliable. This demonstrates that the media is suitable for supporting IoT learning activities within hybrid learning environments.

In addition to its validity, the learning media demonstrated a very high level of practicality. The practicality test involving 15 students resulted in a practicality percentage of 91.33%, categorized as "Very Practical." This finding indicates that the media is easy to use, efficient, and well received by learners. The use of Wokwi Simulation enables students to perform IoT practical activities independently without being constrained by physical laboratory limitations.

Overall, the integration of Wokwi Simulation into IoT learning media provides a flexible and cost-effective solution for hybrid learning implementation. By reducing dependency on physical hardware while maintaining the quality of practical learning experiences, the developed media offers a sustainable alternative for IoT education in vocational and higher education contexts. Future research is recommended to expand the learning media by incorporating more complex IoT modules and a wider range of sensors to support advanced competency development.

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