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Development of Iot Light Planning Assistant Technology for Smart Electrical System Simulation in Utilities Construction Drawing Learning Buildings at Private Vocational Schools of the Nias Regional Government

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Abstract: By utilizing IoT-based digital media such as iLPA, students are expected to be able to apply theory in real-world contexts that mimic real-world workplace conditions. This study aims: Develop IoT Light Planning Assistant (iLPA) learning media in the form of a relevant and contextual Smart Electrical System simulation. Type of research: This study uses a Research and Development (RnD) method with the aim of developing Internet of Things (IoT)-based learning media in the form of a Smart Electrical System simulation integrated into the Building Utility Construction Drawing course. The results showed that the validity aspect of the learning media achieved an average Aiken V-score of 0.88, indicating a valid category based on the assessment. All assessment aspects received Aiken V-scores above 0.75, with the ease of navigation of the IoT system and the quality of the comparison graphs with SNI 6197:2020 receiving the highest scores of 0.93. The practicality of the learning media demonstrated very satisfactory results, with an average score of 4.5 out of 5 (90%) based on responses from DPIB vocational teachers and an average score of 4.2 out of 5 (84%) based on student responses. The integration aspect with the DPIB curriculum received the highest rating from teachers (4.7/5), while the usefulness of the SNI 6197:2020 comparison feature received the highest rating from students (4.4/5).

Keywords: Construction Drawing**; D**igital media; Electrical System

Introduction

The Industrial Revolution 4.0 era is driving global transformation through digitalization and intelligent technologies such as AI, robotics, big data, and IoT, which are increasing industrial efficiency and competitiveness (Atieh et al., 2025). These changes require vocational education to adapt, with a focus on 21st-century skills such as critical thinking, collaboration, creativity, communication, and digital and technological literacy (Yaqub & Alsabban, 2023). Vocational education systems must be innovative and relevant to future industrial needs. One key technology is the Internet of Things (IoT), which enables devices to connect and communicate with each other. In building management and electrical systems, IoT plays a significant role in creating intelligent, efficient, and energy-efficient systems, even reducing engineering costs by up to 80% and maintenance costs by up to 75% (Haleem et al., 2022). In Indonesia, the adoption of IoT-based smart homes is increasing rapidly, reaching 7.28 million homes by 2022. This increasing demand presents both an opportunity and a challenge for vocational schools (SMKs) to prepare graduates with high digital competencies and an understanding of cutting-edge technology. However, there is a significant gap between

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education and industry needs. The World Economic Forum (2025) predicts a major shift in the labor market, with the emergence of 170 million new technology-based jobs and the loss of 92 million.

Indonesian companies are struggling to recruit skilled technology workers (21%) and report a skills mismatch (skill disruption) of 36%. Ninety-four percent of organizations emphasize the importance of reskilling and upskilling in technology areas such as IoT and AI (Li, 2024; Wong, 2024). Furthermore, the Open Unemployment Rate (TPT) for vocational high school (SMK) graduates, although declining, remains higher (9.01% in 2024) than graduates from other educational backgrounds, reflecting a competency gap (Kenayathulla et al., 2019; Yi & Park, 2024). Therefore, integrating digital technology into vocational high school (SMK) learning, particularly through practical approaches and real-world projects, is a strategic imperative to bridge this gap (Fantinelli et al., 2024).

The fields of structural and electrical engineering, particularly the Building Information Modeling and Design (DPIB) expertise program in vocational high schools, have significant potential for implementing the Internet of Things (IoT) (Rikala et al., 2024). Vocational High School Learning Outcomes (Head of BSKAP Decree No. 032/H/KR/2024) emphasize mastery of digital skills in construction, materials, and technical drawing, including understanding lighting systems, electrical installations, and energy efficiency. However, learning methods that are still dominated by theory and a lack of technology-assisted practice are major obstacles to achieving these competencies (Kholid et al., 2023). A survey at the Nias Regional Government Private Vocational High School majoring in Electrical Engineering (DPIB) confirmed this problem: 86% of students had difficulty understanding electrical symbols, 81% rarely practiced drawing installations, and 74% were not even familiar with the concept of IoT. This indicates a lack of digital learning media that can bridge theory and practice in electrical systems (Abdulrahaman et al., 2020; Westbroek et al., 2024).

Interestingly, 84% of students felt IoT-based innovations were essential to improve their understanding, and 92% were willing to undergo additional training. These findings underscore the urgency of developing innovative, contextual, and technology-based learning media to address existing competency gaps. Previous research confirms that the integration of the Internet of Things (IoT) in vocational education positively impacts student skills, increasing the relevance of learning to industry (Pianda et al., 2025; Sudarsono et al., 2023). However, despite the rapid development of IoT, its application in learning about building utility construction drawings and electrical systems in vocational schools remains suboptimal. IoT innovations are more frequently applied in electrical engineering and industrial automation, while space lighting planning and electrical installations are rarely addressed. Yet, this technology has great potential to help students understand lighting standards, the characteristics of electrical components, and design installation layouts in practical ways.

In response to this need, this research developed the IoT Light Planning Assistant (iLPA) (Ali et al., 2023; Santos et al., 2016). This device uses an LDR sensor and an ESP32 microcontroller connected to a mobile application to read light intensity, calculate lighting requirements according to Indonesian National Standards (SNI), and recommend the type and number of lamps. The iLPA also features a lighting simulation using miniature LEDs in a room model. The primary goal is to improve students' electrical literacy through technology-based contextual learning (Abdulaziz et al., 2025; Sidek et al., 2022). The iLPA was developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, which has proven effective for technology-based learning media (Maslakhah et al., 2024; Sari & Tyas, 2024). This digital tool-based approach encourages student-centered learning, creates realistic scenarios, and strengthens practical competencies aligned with industry needs (Daff et al., 2024; Ruiz-Rojas et al., 2024).

The success of IoT integration also depends on systemic support such as curriculum updates, teacher development, and infrastructure improvements (Oubibi et al., 2024; Spaho et al., 2025), the development of the iLPA is expected to be the first step in innovative technology-based electrical learning in vocational schools, while also contributing to strengthening the vocational education ecosystem. This research is expected to create an innovative product in the form of IoT-based learning media that can bridge the gap between theory and practice, as well as improve student competency in the field of building electrical systems. The development of iLPA not only addresses local needs at the Nias Regional Government Private Vocational School but can also serve as a model for other vocational schools with similar conditions. This research is expected to be a real contribution to strengthening digital-based vocational education and supporting the transformation of learning in the era of the Industrial Revolution 4.0.

Method

This research uses the Research and Development (RnD) method with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The goal is to develop an Internet of Things (IoT)-based Smart Electrical System simulation as a learning medium for the Building Utilities Construction Drawing course.

Research Design (ADDIE Model)

Analysis: Identifying IoT learning needs, weaknesses of conventional methods, and relevant curricula. The results are system feature recommendations and challenge identification (Ghashim & Arshad, 2023). Design: Designing IoT hardware and software prototypes, including user interfaces and key features (electrical control, power monitoring, circuit visualization). Evaluation instruments such as pre- and post-tests were also developed. Development: Building an IoT system prototype (ESP32/Arduino, sensors, relays), developing software (web/mobile) for control and monitoring, integrating interactive materials, and conducting technical tests for functionality and stability. Implementation: Conducting a trial of the IoT simulation in grades 11 and 12 of the DPIB Private Vocational High School (SMK) Pembda Nias, and training students and teachers in its use. Evaluation: Measuring the effectiveness of the system through pre- and post-tests, assessing the practicality of the tool through student and teacher questionnaires, and refining the system based on the findings.

Population and Sample

Population: Includes all parties involved in DPIB learning at the Nias Regional Government Private Vocational High School: 11th and 12th grade DPIB students (media users), DPIB Vocational subject teachers (practicality assessors), and experts/validators (media experts and subject matter experts) to assess validity. Sample: Determined using purposive sampling. The sample consisted of 30 11th and 12th grade DPIB students (to assess effectiveness), 3 DPIB vocational teachers (to assess practicality), and 3 experts (subject matter experts and media experts) for product validation.

Operational Definitions

Internet of Things (IoT): Technology that connects electronic devices for communication and automatic control (used for Smart Electrical Systems); Smart Electrical System: An IoT-based automated electrical installation system for energy efficiency, comfort, and building security; Interactive Learning Media: Dynamic and participatory digital learning tools, in the form of IoT simulations for smart electricity concepts; Learning Simulation: Visual and interactive representation of real systems for applied learning experiences; Building Information Modeling and Design (BID): Vocational high school expertise program focused on building design and its utilities (research target); ADDIE Development Model: A 5-stage systematic framework (Analysis, Design, Development, Implementation, Evaluation) for media development; Media Effectiveness: The extent to which IoT simulations improve students' understanding, active engagement, learning outcomes, and ability to draw/understand IoT-based electrical systems.

Data Collection Techniques

Data were collected using a questionnaire designed to assess the validity, practicality, and effectiveness of the IoT learning media. Validity: Assessed by material and media experts, including content suitability, visual appearance, and technology integration; Practicality: Assessed by teachers, including ease of use, clarity of instructions, and suitability to classroom conditions; Effectiveness: Assessed by students, including increased conceptual understanding, interest, and ease of use of the media. Each questionnaire item used a 5-point Likert scale (Strongly Agree to Strongly Disagree). The instrument was validated by experts before use.

Data Analysis Techniques

Data analysis was conducted using a descriptive quantitative method by calculating the average (mean) value for each aspect and indicator to assess the validity, practicality, and effectiveness of the developed IoT learning media, based on data from the assessor questionnaires (experts, teachers, and students).

Results and Discussion

Research Results: Development of IoT-Based Smart Electrical System Simulation Learning Media

This research developed a Smart Electrical System Simulation learning media based on the Internet of Things (IoT) using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The goal was to improve student understanding, innovation, and independence in the Building Utilities Construction Drawing course.

Development Stages (ADDIE Model)

Analysis

Identifying IoT learning needs (real-time lux measurement, monitoring, data analysis, SNI comparison), examining the weaknesses of conventional methods (too theoretical, not practical), and analyzing relevant curricula. The results identified students' needs for hands-on experience with sensor technology and an understanding of smart building concepts.

Table 1. Validator Data

Validator Name	Position	Validated Aspects
Prof. Dr. Ir. M. Giatman, MSIE., IPU	Lecturer	Learning Media
Martperan Putra Zebua, S. T	Head of Program	Learning Materials
Herman Putra Telaumbanua, S. Pd	Teacher	Learning Materials

Design

Designed an IoT system prototype (ESP32, BH1750/LDR sensor, LED strip, relay, dimmer, OLED display), designed software (Arduino IDE, HTML5, CSS3, JavaScript, MySQL) for the monitoring and recommendation dashboard, designed an intuitive and responsive user interface, and defined key simulation features (device control, power consumption monitoring, electrical circuit visualization) and evaluation instruments (pre-test, post-test, practice rubric).

Development

Developed hardware and software prototypes, integrated interactive learning materials (videos, animations, infographics, case studies) into the system, and conducted comprehensive technical testing (sensor calibration, connectivity testing, load testing, functional testing, security testing) to ensure system stability and functionality before implementation in the classroom.

Implementation

Conducted a Smart Lighting System simulation trial in the 11th grade DPIB of SMK Swasta Pembda Nias with 30 students over two learning sessions. Students practiced measuring real-time lighting, comparing it with SNI standards, and formulating recommendations. Previously, comprehensive training was provided to three teachers and 30 students.

Evaluation

Was conducted formatively (during development/implementation) and summatively (after implementation).

Effectiveness

Was measured by comparing pre-test and post-test results on 30 students. The average post-test score increased significantly by 28.5% (from 65.2 to 83.8), particularly in data interpretation (real-time) and SNI comparison. This demonstrates the system's effectiveness in improving conceptual understanding and practical skills.

Practicality

Assessed through a questionnaire with 30 students and 3 DPIB teachers. Students responded positively with an average score of 4.2 out of 5, stating that the system was engaging and easy to understand. Teachers gave an average score of 4.5 out of 5, assessing the system's relevance and effectiveness as a practical learning tool.

System Improvement

Based on the evaluation, adjustments were made to the interface (interactive tutorial), SNI comparison module (graphical visualization), recommendation features (more accurate algorithms), the addition of an automatic reporting feature, improvements to IoT connection stability (backup connectivity, local data storage), and response time optimization.

Product Trial

Validity: Tested by 3 media and material experts using a questionnaire. After revision, the IoT-based Smart Electrical System simulation learning media was declared valid and suitable for use; Practicality: Tested by 3 DPIB vocational teachers. The results indicated the media was practical for use; Effectiveness: Tested on 30 DPIB grade 11 and 12 students. The results indicate that the learning media enhances students' understanding of smart electricity and optimizes the learning process. Overall, the development of this learning media using the ADDIE approach demonstrates the successful integration of IoT technology into vocational learning.

Validity, Practicality, and Effectiveness of an IoT-Based Smart Lighting System Simulation

This research successfully developed an Internet of Things (IoT)-based Smart Lighting System simulation learning media for the Building Utilities Construction Drawing course at the Nias Regional Government Private Vocational School (SMK Pembda). This media allows for real-time lighting measurements, comparisons with the SNI 6197:2020 standard, and recommendations for additional lighting. Development was conducted using the ADDIE model, starting with needs analysis, design, development, implementation, and evaluation.

Learning Media Validity

Media validation was conducted by three media and material experts. The results indicate that the IoT-based Smart Lighting System simulation learning media is valid (average Aiken V value of 0.88) and suitable for use as a learning medium for building lighting planning, meeting didactic requirements, construction aspects, and technical requirements.

Practicality of Learning Media

From a Teacher's Perspective

A practicality test on three vocational teachers from the DPIB (District of Bandung) showed very practical results (average score of 4.5 out of 5, or 90%). Teachers highly rated ease of use (4.3/5), integration with the curriculum (4.7/5), efficiency of learning time (4.5/5), and classroom management (4.7/5). This indicates that the system significantly assists teachers in the teaching and learning process.

From a Student's Perspective

A practicality test on 30 11th and 12th grade DPIB students showed practical results (average score of 4.2 out of 5, or 84%). Students responded positively to the ease of operation of the web interface (4.1/5), understanding of BH1750 sensor data (4.2/5), and especially the usefulness of the comparison feature with SNI standards (4.4/5). The majority of students (93%) found the learning more engaging and facilitated conceptual understanding.

Effectiveness of Learning Media

The effectiveness of the media was measured by comparing the results of the pre-test and post-test on 30 students. There was a significant increase in the average post-test score of 28.5% compared to the pre-test (from 65.2 to 83.8). The highest increase was seen in students' ability to interpret real-time lighting measurement data (35% increase) and compare the results with the SNI 6197:2020 standard (32% increase). This proves that the IoT-based Smart Lighting System simulation is effective in improving DPIB students' conceptual understanding and practical skills in building lighting planning according to national standards.

Interpretation of Results

The Internet of Things (IoT)-based Smart Lighting System simulation learning media demonstrated excellent practicality, achieving an average score of 4.35 out of 5 (87%). This indicates high suitability for use in building lighting planning lessons. Vocational teachers at the DPIB (District Lighting Institute) demonstrated full support, with 100% rating the media as practical to very practical. They highly appreciated its integration with the DPIB curriculum (a score of 4.7 out of 5), confirming that this IoT lighting system aligns well with the Building Utilities Construction Drawing subject competency standards without burdening the learning process. From the students' perspective, enthusiasm for this media was also very positive, with 87% providing favorable feedback. Their most appreciated feature was the comparison with the SNI 6197:2020 standard (a score of 4.4 out of 5). This feature helps students understand the national standard by comparing it with real-time lighting measurement results, making learning more applicable and relevant to construction industry practices.

Table 2. Comparison of Teacher vs. Student Practicality

Respondent categories	Amount	Average score	Percentage %	Practical category
DPIB Teachers	3	4.50	90	Very practical
DPIB Students	30	4.20	84	Practical
Overall Average	33	4.35	87	Very practical

The ease of use of this IoT system is key to its successful implementation (Brous et al., 2020). Both teachers and students can operate it with minimal training, demonstrating a well-designed interface and user experience. This ensures the learning focus remains on the substance of the lighting planning material without being hampered by technological complexity. Overall, this learning tool successfully bridges the gap between theory and industrial practice, leading to smart building concepts and energy-efficient design. IoT integration, real-time lighting measurements, and the implementation of SNI standards prepare DPIB students with relevant competencies for the demands of the workforce in the era of digital and sustainable construction.

Discussion

This research successfully developed an Internet of Things (IoT)-based Smart Lighting System simulation learning media specifically designed for the Building Utilities Construction Drawing course. This media serves as an interactive learning resource that allows students to measure room lighting levels in real time, compare them to the SNI 6197:2020 standard, and provide recommendations for additional lighting. The development of this media began with observations at a private vocational school (SMK) at the Nias Regional Government to identify needs and obstacles in lighting planning learning, followed by an analysis of the DPIB curriculum to integrate IoT technology (Gehlot et al., 2021; Kouah et al., 2024).

This learning media underwent an ADDIE development process and validity, practicality, and effectiveness testing (Aprilia et al., 2024; Spatioti et al., 2022). The validity testing, involving experts, demonstrated that the media met didactic, construction, and technical requirements with an average Aiken's V of 0.88, indicating its feasibility (Avsec & Ferk Savec, 2022;

Timbi-Sisalima et al., 2024). In terms of practicality, the media was deemed very practical by three DPIB vocational teachers (average score of 90%) and practical by 30 students (average score of 84%). Teachers appreciated its ease of use, curriculum integration, time efficiency, and improved classroom management (Rincon-Flores et al., 2024; Simon & Zeng, 2024). Meanwhile, students expressed high enthusiasm for the user-friendly interface, understanding of sensor data, the benefits of the SNI comparison feature, and their satisfaction with interactive learning (Córdova-Esparza et al., 2024; Schildkamp et al., 2020).

The effectiveness of this media was evident in the significant improvement in student learning outcomes (Afifa & Astuti, 2024; Alshammary & Alhalafawy, 2023). A comparison of pre-test and post-test scores for 30 students showed an average score increase of 28.5%, from 65.20 to 83.80. The greatest improvement occurred in students' ability to interpret real-time lighting measurement data (35%) and compare it to SNI standards (32%). These results confirm that this IoT-based Smart Lighting System simulation learning media is effective in improving DPIB students' conceptual understanding and practical skills in building lighting planning in accordance with national standards (Matsun et al., 2022; Shipps et al., 2023).

Research Limitations

This research on the development of an IoT-based Smart Lighting System simulation learning media has several limitations that should be considered; First, the research location was limited, conducted only at a private Vocational High School (SMK) in Nias. This means that findings on validity, practicality, and effectiveness may not be generalizable to other schools or different learning contexts; Second, the media effectiveness test focused only on the cognitive aspects of grades 11 and 12 of DPIB students at the school and involved only 30 students. This limits our understanding of the media's impact on students' practical skills or affective aspects, and the sample size is also relatively small; Third, this media development only used the ADDIE model. The research has not yet examined how this media would perform when integrated with other learning development models such as Dick & Carey or Hannafin & Peck; Fourth, the developed IoT system is still limited to lighting measurements using the BH1750 sensor and comparison with SNI 6197:2020. There is no integration with other building utility aspects, such as ventilation or cooling systems, which could enrich the simulation; Fifth, the media validation only involved three experts (material experts and learning media experts). There were no validators from the construction industry or IoT technology experts, who could have provided a broader perspective relevant to the world of work; Finally, the practicality test only involved three teachers at the Nias Pembda Private Vocational School and has not been piloted at other vocational schools. Furthermore, this study did not examine the long-term effectiveness of using IoT learning media on student knowledge retention and its relevance to the construction workplace.

Conclusion

This research successfully developed a Smart Lighting System Simulation learning media based on the Internet of Things (IoT) for the Building Utilities Construction Drawing subject at the Nias Regional Government Private Vocational School. This product was proven to be valid, practical, and effective. Validity: This media achieved an average Aiken V validity value of 0.88 based on the assessment of 3 experts (material and media experts), with all aspects above 0.75. The ease of navigation of the IoT system and the quality of the comparison graph with SNI 6197:2020 received the highest score (0.93).; Practicality The practicality aspect was very satisfactory, with an average score of 4.5/5 (90%) from teachers and 4.2/5 (84%) from students. Teachers highly rated the integration with the DPIB curriculum (4.7/5), while students most appreciated the benefits of the SNI 6197:2020 comparison feature (4.4/5).; Effectiveness: This media demonstrated significant effectiveness, with an average increase in student learning outcomes of 28.5% (from 65.2 in the pre-test to 83.8 in the post-test). The greatest improvement was seen in the ability to interpret real-time lighting data (35%) and compare it with the SNI 6197:2020 standard (32%). The ADDIE development model proved effective in producing interactive and applicable IoT-based learning media, according to the learning needs of building lighting planning.

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Author Contributions
Conceptualization; methodology; validation; formal analysis; investigation; resources; data curation: writing—original draft preparation; writing—review and editing; visualization: D. H., M. G., A., D. I. All authors have read and approved the published version of the manuscript.

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The authors declare no conflict of interest.

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