Develop An Educational Innovation for A Training Set on Embedded Iot: Learning Skills for High School Students.

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Abstract

This research addresses the scarcity of hands-on IoT learning resources in secondary education, which hinders students' practical and problem-solving skills. The study focuses on developing and evaluating an educational innovation with two objectives: 1) to develop an IoT-based embedded system training package for upper secondary students, and 2) to assess its efficiency. The participants in this study consisted of 15 experts and instructors. The research instruments included: (1) a content suitability evaluation form, (2) the educational innovation package for IoT-based embedded system learning, and (3) a practical skills assessment form. The statistical methods employed for data analysis comprised item validity, item difficulty, item discrimination, reliability, arithmetic mean, standard deviation, and efficiency values based on the E1/E2 criterion.

The research findings revealed that:

1. The educational innovation package for IoT-based embedded system learning for upper secondary school students consisted of three main components: (1) instructional materials, (2) a prototype training model for practical skills, and (3) a user manual for the educational innovation package.

2. The educational innovation package demonstrated an efficiency value of 81.25/82.00, which exceeded the established standard criterion of 80/80.

Keywords: Iot Training Kit, Embedded Systems, ADDIE Model, Practical Skills Assessment

Introduction

At present, the teaching and learning of Computational Science and Embedded Systems at the upper secondary education level face significant challenges, particularly the shortage of hands-on learning materials, combined with the complexity of Internet of Things (IoT) technologies, which are difficult for students to comprehend within limited instructional time. As a result, learners often lack problem-solving skills and the ability to apply technological knowledge to real-world situations. Meanwhile, educational institutions at all levels have increasingly emphasized the integration of technology and innovation in both educational management and instructional practices to enhance learning effectiveness, reduce educational inequality, and promote lifelong learning. This approach enables learners to access learning resources and develop their learning potential anytime and anywhere. In response to these challenges, the researcher developed an innovative skill-training kit to bridge theoretical knowledge with practical application and to enhance students' digital competencies in alignment with the demands of the contemporary digital society.

The integration of technology and innovation has become a driving force in reshaping education across all dimensions, including curriculum development, instructional design, learning media, assessment methods, and school management. While the overall adoption of technology and innovation in education appears beneficial, closer examination reveals significant challenges. Many educational institutions remain underprepared for effectively implementing technology in teaching and learning. Teachers, in particular, often lack expertise in using technology and innovation, as well as access to modern learning tools that enable practical, hands-on experiences. Consequently, learners face difficulties in applying theoretical knowledge to real-world practice, which hinders their ability to extend knowledge toward innovation and problem-solving in daily life. To address this issue, the Ministry of Education has introduced computational science as a compulsory subject in the Basic Education Core Curriculum B.E. 2551 (revised B.E. 2560). This subject, required from Grade 1 through Grade 12, emphasizes three key areas: (1) computational thinking, (2) digital technology, and (3) media and information literacy. Together, these domains aim to equip learners with systematic problem-solving skills, technological competence, and critical awareness of media and digital information.

In response to these educational challenges, the research team has proposed a project titled Develop an educational innovation for a training set on embedded IoT learning skills for high school students. The primary objective is to develop innovative learning kits that teachers can use as tools to design computational science activities, bridging theoretical knowledge with practical application. These kits will allow learners to practice systematic thinking, engage in hands-on experiences according to their own potential, and develop teamwork skills. By incorporating Internet of Things (IoT) technology—electronic devices capable of connecting and communicating automatically via the Internet—the learning kits provide real-life applications, such as smart homes, smart networks, or smart farming. Learners can practice programming and interacting with devices such as temperature sensors, humidity sensors, lighting controls, or automated water valves. This hands-on experience enables students to concretely apply theoretical knowledge to practical scenarios. The research team strongly believes that the developed learning kits will contribute to effective teaching and learning in computational science, fostering creativity, problem-solving skills, teamwork, and the ability to extend knowledge toward developing innovations that improve efficiency and address real-life challenges.

Objectives of the Study

In this research, the objectives were set as follows:

1. To develop an educational innovation in the form of an IoT-based embedded system learning skills training kit for senior high school students.

2. To evaluate the effectiveness of the educational innovation in the form of an IoT-based embedded system learning skills training kit for senior high school students.

Conceptual Framework

Input	Process	Output
1. Study the problems of teaching and learning computer science. 2. Study educational innovations. 3. Study the development process of learning skills training kits. 4. Study embedded IoT systems. 5. Study IoT devices. 6. Study related concepts and theories.	1. ADDIE Model 5 step ▪ Analysis ▪ Design ▪ Development ▪ Implementation ▪ Evaluation 2. Find out the effectiveness of the skill training set	Educational innovation for a training set on embedded IoT learning skills for high school students that meets the specified criteria

Figure 1: Conceptual Framework of the Research on Developing an Educational Innovation: An Embedded IoT Microcontroller Learning Training Kit for Upper Secondary School Students.

From Figure 1, the research team conducted a study of relevant concepts and theories, including: investigating issues in teaching and learning in the subject of Computational Science, exploring educational innovations, examining the development process of learning skills training sets, and studying IoT embedded systems and IoT devices. These studies were conducted to Develop an educational innovation for a training set on embedded IoT learning skills for high school students. The development followed the ADDIE instructional design model, which comprises five stages (Kevin Kruse, 2008), with the aim of producing an effective learning skills training set for IoT embedded systems that meets the established efficiency criteria.

Literature Review

ADDIE Model

The ADDIE Model is a systematic process or method for designing instruction and developing learning materials. This concept originated at Florida State University's Center for Educational Technology, where it was created and later developed into a widely recognized instructional design process known as the ADDIE Model. It is defined as a systematic approach to instructional design and development that has gained worldwide acceptance. The term ADDIE represents the five key stages of the design process (Kevin Kruse, 2008): Methodological Framework: The Enhanced ADDIE Model

A-Analyze: Conducted a needs analysis by synthesizing classroom evidence, including teacher interviews and student performance data, to identify specific barriers in IoT education.

Outcome: Design Specifications that directly address authentic classroom challenges.

D-Design: Structured a curriculum and lesson plans integrating 21st-century skills, with a strategic focus on creative problem-solving and computational thinking. Outcome: An Instructional Blueprint encompassing lesson frameworks and hands-on activity guidelines.

D-Develop: Produced an IoT training kit prototype alongside supplementary media, such as activity sheets and manuals, validated for quality and alignment by subject-matter experts.

Outcome: A comprehensive and validated IoT embedded system skill training package.

I-Implementation: Deployed the training kit with a diverse sample group, utilizing reflective notes to document real-time learning behaviors and challenges encountered during the session.

Outcome: Empirical data on student engagement and behavioral patterns within a practical context.

E-Evaluate: Conducted a holistic assessment using E1/E2 efficiency criteria (quantitative) and qualitative feedback to measure learning transformation across cognitive, psychomotor, and affective domains.

Outcome: A final evaluation report demonstrating the innovation's efficacy in fostering holistic student development.

The hallmark of this model is its seamless systemic integration, utilizing outputs from each phase as data inputs for subsequent stages to minimize errors. Combined with formative evaluation, it allows for immediate quality enhancements throughout the process, ensuring the resulting innovation is precise and achieves maximum instructional efficacy.

Flowchart

Spark Education (2024) summarized that a flowchart is a diagram representing the sequential steps of a logical process or algorithm, using interconnected symbols. It facilitates the understanding of procedures, problem analysis, and problem-solving. A flowchart consists of standard symbols representing different steps, such as the start/end of a process, process execution, decision-making, and input/output operations. These symbols are connected by arrows indicating the direction of data flow.

Algorithm

According to Monlamai Vichienwanitchkul (2019), an algorithm is "a set of commands or step-by-step conditions that enable a robot to perform the tasks we assign." To enable robots, computers, or electronic devices to clean floors, move, or collect objects, a specific set of instructions must be designed for those tasks. Algorithms can also be applied in everyday life, for example, when organizing daily activities based on urgency, importance, or personal preferences.

Learning Activities Set

Wanwisa Prapasri (2018) stated that a learning activity package refers to a completed instructional medium that serves as an innovation created by the instructor. It consists of a title, instructions, objectives, content, learning activities, and assessment and evaluation procedures conducted both before and after learning. The instructor acts as a facilitator, guiding students in performing the learning activities.

Internet of Things (IoT)

Tom Bradicich (2015) refers to the Internet of Things (IoT) refers to a network of devices, objects, or entities embedded with sensors, software, and communication technologies that enable them to connect and exchange data via the Internet. The goal is to allow these entities to communicate and operate autonomously, thereby supporting decision-making, control, and the development of efficient and sustainable services and experiences. The core components of IoT can be categorized into five main elements:

1. Devices/Things-Physical objects equipped with sensors and actuators to collect and respond to data, such as smartwatches, intelligent cameras, and industrial machines.
2. Connectivity/Network-Communication channels for data transmission, including Wi-Fi, Bluetooth, Zigbee, 4G/5G, and LoRaWAN.
3. Gateway & Edge Computing-Devices that aggregate data from multiple sources and perform preliminary processing to reduce latency.
4. IoT Platform/Cloud Services-Centralized systems for data storage, processing, analysis, and service provision, such as dashboards, APIs, and AI-powered analytics.
5. Applications-Real-world use cases of IoT, including Smart Homes, Smart Cities, Precision Agriculture, Healthcare, and Industry 4.0.

IoT and ADDIE Model

The integration of IoT into the ADDIE Model represents a systematic fusion of smart data technology with the instructional design process. IoT functions as a pivotal tool for gathering deep behavioral insights during the Analysis phase and serves as the infrastructure for real-time interaction during Implementation. Meanwhile, the ADDIE Model provides the strategic framework that transforms vast data from connected devices into purposeful educational innovations, enabling precise, real-time evaluation and quality enhancement tailored to the 2025 digital learning landscape.

Embedded Systems

Van Den Berg (2007) discussed embedded systems as computer systems specifically designed to perform dedicated functions within particular products or operations. These systems are embedded in everyday devices or specialized industrial applications, distinguishing them from general-purpose computers that are designed to perform a wide range of tasks. In the future, embedded systems are likely to evolve by integrating emerging technologies, such as cloud-based data processing and artificial intelligence (AI), to enhance their operational capabilities. Moreover, the growing adoption of the Internet of Things (IoT) will further increase the importance of embedded systems in connecting and controlling everyday devices.

Skill Training Package

Wanwisa Praphasri (2018) refers to the term skill training package refers to a systematically designed instructional medium intended to facilitate learners' understanding of specific lessons or subject matter. It is developed with the primary objective of providing structured opportunities for learners to practice and enhance their learning skills in accordance with their individual potential.

A skill training package is characterized by its emphasis on learner-centered pedagogy, aiming to promote accurate skill acquisition, reinforce comprehension, and foster sustainable learning outcomes. Beyond content mastery, such packages contribute to the cultivation of desirable learner attributes, including the ability to think critically, responsibility, and a positive attitude toward lifelong learning.

Although skill training packages may differ in form, content, or instructional approach, their fundamental purpose remains consistent: to provide diverse learning experiences that enable learners to develop a wide range of skills and to achieve the specified educational objectives.

Integrating 21st Century Skills Frameworks to Enhance IoT-Based Embedded Systems Learning Innovations

The researcher systematically integrates 21st Century Skills into the training kit's learning activities by aligning technical development with international competency standards, such as the P21 Framework and OECD 2030. This integration encompasses computational thinking, complex problem-solving, and digital literacy. By defining clear indicators for each activity, the theoretical foundation and educational value of the innovation are elevated to meet international standards. This approach ensures a holistic development framework for learners, concretely addressing the demands of the 2025 digital labor market

Research Methodology

This study investigates pedagogical challenges and needs within Computational Science by synthesizing relevant theories, including learning frameworks, skill training modules, practical skill development, and the Internet of Things (IoT). These insights were applied to develop an educational innovation in the form of a learning skill training module. To ensure high-quality validation, the researcher employed purposive sampling to select subject-matter experts specialized in IoT. The innovation is designed for implementation within high school computer laboratories, emphasizing a hands-on learning approach. This methodological decision aims to align instructional efficiency with students' foundational knowledge and institutional resources, ensuring a precise and effective enhancement of digital competencies for the 2025 landscape before full-scale implementation with the target group.

How to create research tools

The research instruments were developed and validated through the following procedures:

1. Content Appropriateness Evaluation Form

This instrument was designed to establish guidelines for organizing instructional content, activities, and performance assessment tools for each learning unit, ensuring their alignment with behavioral objectives. Five content experts were invited to evaluate the instrument, and the index of item-objective congruence (IOC) for each item was 0.81.

2. Instructional Innovation: Learning Skill Training Package

This package served as an instructional tool for students in the subject of computational science. It aimed to foster systematic thinking, encourage self-directed practice, and enhance learners' proficiency through hands-on activities. The training package was developed based on the ADDIE instructional design model to ensure both teaching effectiveness and successful learning outcomes.

3. Performance Skills Assessment Form

This instrument was employed to measure students' practical skills after engaging with the learning skill training package. Three performance-skill experts evaluated the instrument, and the index of item-objective congruence (IOC) for each item was 0.83.

Data collection

Data collection has the following steps:

1. Content Appropriateness Evaluation Form

The data collection procedures consisted of the following steps: studying the process of evaluating content appropriateness, selecting experts, coordinating with the experts, distributing the evaluation forms, and collecting the completed forms from the experts for subsequent data analysis.

2. Educational Innovation: Learning Skill Training Package

The data collection procedures consisted of the following steps: studying the process of determining the effectiveness of the educational innovation (learning skill training package), selecting the sample group, coordinating with the sample group facilitators, implementing the learning skill training package with the selected sample group, collecting the resulting data, and analyzing the data to assess effectiveness against the established criteria before proceeding with actual implementation.

3. Practical Skills Assessment Form

The data collection procedures consisted of the following steps: studying the process of assessing practical skills, planning the implementation, coordinating with facilitators of the target group, administering the practical skills assessment form to measure learners' practical skills, and collecting the assessment data for further analysis to determine learners' skill levels.

Data Analysis

Data Analysis Procedures:

1. Content Appropriateness Analysis

The content appropriateness evaluation form was used to collect data from experts. The results were summarized, and the evaluated content was subsequently applied in the development of the educational innovation, namely the learning skill training package.

2. Effectiveness Analysis of the Educational Innovation

The effectiveness of the learning skill training package was analyzed and compared against the standard criterion of 80/80. The results showed an effectiveness level of 81.25/82.00, which exceeded the established criterion. This indicates that the innovation can be effectively applied in instructional practice.

3. Practical Skill Assessment Analysis

The practical skill assessment form was administered to learners after participating in the learning skill training package. The analysis revealed a content validity index of 0.93, a difficulty index (P) ranging from 0.40 to 0.72, a discrimination index (D) ranging from 0.30 to 0.70, and a reliability coefficient of 0.91.

Research Finding

1. Development Results of an Educational Innovation: Embedded IoT Learning Skill Training Kit for Upper Secondary Students.

The development of the educational innovation, namely the IoT Embedded System Learning Skill Training Kit for high school students, yielded the following results. The research found that the innovation consists of three main components:

1. Learning Support Documents, which include:
    - 1.1 Lesson Plans
        - 1.1.1 Lesson Plan 1: Introduction to IoT (Internet of Things)
        - 1.1.2 Lesson Plan 2: Program Design Using Flowcharts
        - 1.1.3 Lesson Plan 3: Programming with IoT Devices
        - 1.1.4 Lesson Plan 4: Building an Automated Plant Watering System

1.2 Knowledge Sheets
1.3 Activity Sheets
1.4 Activity Records
1.5 Unit Tests

2. Practical Skill Training Model, which is a set of IoT devices used for teaching in Computer Science courses. This component serves as a guideline for instructors to organize learning activities and as a tool for students to engage in hands-on practice. An example of the practical skill training model is shown in Figure 2.

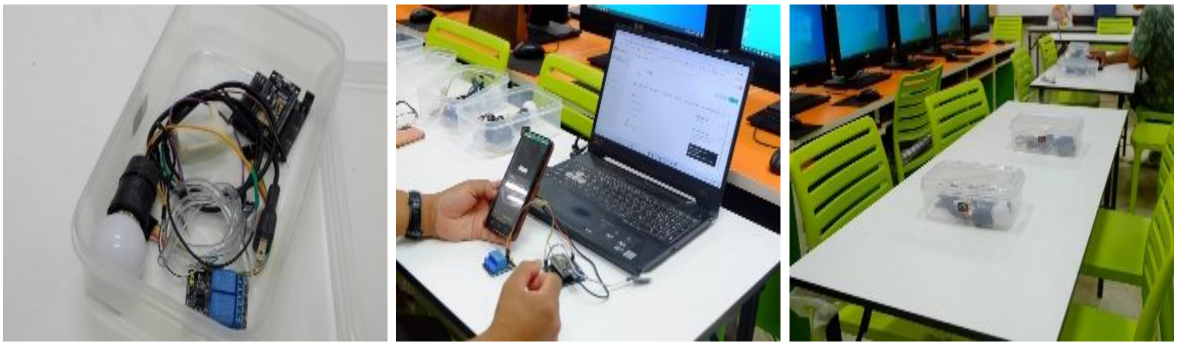

Figure 2: Model of a practical skills training set

From Figure 2, the practical skills training model consists of:

2.1 NodeMCU board
2.2 ESP8266 chip
2.3 Arduino IDE software
2.4 Operation of the Blynk App
2.5 WiFi signal
2.6 Sensors
2.7 Relay

3. The user manual for the educational innovation of the skills training set includes:

3.1 User manual for the IoT skills training educational innovation for instructors.
3.2 User manual for the IoT skills training educational innovation for learners.

2. Results of the Effectiveness of the Educational Innovation: IoT-Based Embedded System Learning Skill Training Set for Upper Secondary Students.

To evaluate the effectiveness of the educational innovation, the IoT-based embedded system learning skill training set developed by the research team for upper secondary students, a sample group of 30 students was selected. The process effectiveness (E1) was calculated as the percentage of the average scores obtained from completing activity sheets, project work, and post-lesson tests across four instructional plans. The outcome effectiveness (E2) was calculated as the percentage of the average scores obtained from the practical skill assessment conducted at the end of the experiment. The results are presented in Table 1, according to the E1/E2 effectiveness criteria.

Table 1 Effectiveness of the Educational Innovation: IoT-Based Embedded Systems Learning Skill Training Kit for Senior High School Students.

Students	Percentage of Scores from Unit-Based Activities / Full Score (E_1)				Total (E_1)	Post-Learning Score (E_2)
	Learning Plan 1	Learning Plan 2	Learning Plan 3	Learning Plan 4		
	Activity Sheet 1 (20)	Activity Sheet 2 (20)	Activity Sheet 3 (20)	Activity Sheet 4 (20)	(80)	(20)
1	16	16	17	18	67	16
2	15	16	16	17	64	15
3	16	17	17	18	68	17
4	15	16	16	16	63	16
5	16	17	17	16	66	16
6	16	16	16	17	65	16
7	16	15	16	16	63	17
8	15	16	15	17	63	18
9	16	18	17	18	69	17
10	16	18	16	16	66	16
11	15	18	18	15	66	18
12	14	15	16	17	62	16
13	16	18	18	18	70	16
14	15	16	17	15	63	17
15	15	18	17	16	66	16
16	16	16	18	15	65	15
17	16	18	16	15	65	16
18	15	16	16	16	63	15
19	14	15	16	17	62	16
20	16	15	16	18	65	17
21	16	17	18	15	66	18
22	15	15	16	16	62	16
23	16	16	17	16	65	15
24	15	16	16	15	62	16
25	15	16	17	16	64	16
26	16	17	16	16	65	17
27	16	17	17	18	68	16
28	16	17	17	16	66	18
29	16	16	16	17	65	16
30	16	16	17	17	66	18
together	466	493	498	493	1950	492
average	15.53	16.43	16.60	16.43	65.00	16.40
S.D.	0.63	1.01	0.77	1.04	2.10	0.93
Percentage	77.67	82.17	83.00	82.17	81.25	82.00

Students	Percentage of Scores from Unit-Based Activities / Full Score (E_1)				Total (E_1)	Post-Learning Score (E_2)
	Learning Plan 1	Learning Plan 2	Learning Plan 3	Learning Plan 4		
	Activity Sheet 1	Activity Sheet 2	Activity Sheet 3	Activity Sheet 4		
	(20)	(20)	(20)	(20)	(80)	(20)
E_1/E_2 Efficiency Based on the Established Criterion 80/80				E_1/E_2 Efficiency for the Skill Practice Set 81.25/82.00		

Table 1 shows that the average scores from activity sheets, project assignments, and post-tests across four lesson plans were 65.00 out of 80 points (81.25%). The average post-learning practical skills score was 16.40 out of 20 points (82.00%). These findings indicate that the IoT-based embedded systems learning skills training set for senior high school students is effective, exceeding the preset criterion of 80/80, and can be successfully applied in classroom instruction.

Discussion

The present investigation yielded several critical findings that warrant scholarly discussion, delineated as follows:

1. Educational Innovation: Development of an IoT-Based Embedded System Training Kit The research team conceptualized and developed an IoT-based embedded system training kit for upper secondary school students. This innovation was designed not merely as supplementary instructional material, but as an integrated pedagogical framework systematically linking theoretical constructs with practical applications. Its primary purpose is to cultivate students' ability to engage in structured reasoning, problem-solving, and experiential practice. The design and development process was firmly grounded in established learning theories, thereby ensuring both theoretical rigor and instructional validity. The training kit comprised three principal components: (a) instructional support documents, (b) a prototype model of the training apparatus, and (c) a comprehensive user manual for classroom implementation. This finding is consistent with Supot Suthathum and Nattapong Polsayom (2016), who investigated the development and experimental use of virtual reality–based instructional media for teaching computer hardware and networking devices. His research identified two core dimensions of the innovation, namely the structural composition of the media—including learning content, detailed hardware and network component descriptions, online learning community integration, and operational manuals-and the developmental strategies underlying such media. Empirical results demonstrated that learners exhibited measurable improvements in knowledge acquisition, attributable to the immersive simulation of real-world device operations. In the present study, the development process adhered to the ADDIE instructional design model, a paradigm widely endorsed in educational technology research for its systematic and iterative approach. The efficiency index of the developed innovation was 81.25/82.00, exceeding the predetermined E1/E2 benchmark of 80/80. This performance index substantiates the pedagogical effectiveness of the training kit, confirming that

it not only meets but surpasses the threshold of instructional efficiency. Such results correspond with those of Arasorn Phaochanuan (2011), who developed computer-assisted instructional modules on the topic of energy for lower secondary science students and reported efficiency values of 86/82.75, thereby surpassing the established 80/80 benchmark.

2. Effectiveness of the Innovation: Comparative Outcomes

The study further evaluated the effectiveness of the IoT-based embedded system training kit in comparison with conventional instructional methods. Across all five target schools, students who engaged with the training kit demonstrated statistically significant gains in practical skills relative to peers taught using traditional pedagogical approaches, with significance at the .05 level. These findings underscore the capacity of the innovation to enhance student performance beyond outcomes achievable through conventional classroom practices. The results align with Vasinee Liamsuwan (2015), who developed cooperative learning activity packages utilizing the Team-Assisted Individualization (TAI) technique to enhance presentation skills using Prezi among Grade 9 students. The study revealed that students' post-test scores were significantly higher than their pre-test scores ($p < .05$), and cooperative learning behaviors were rated at a favorable level (mean = 79.35%). Similarly, the findings corroborate those of Jewaree Srichanchai (2023), who developed science training kits through project-based learning combined with the Student Teams Achievement Divisions (STAD) technique for Grade 5 students. That study reported significant improvements ($p < .05$) in analytical thinking, collaborative behavior, and academic achievement after exposure to the training kits. Furthermore, the current findings are reinforced by Natthapong Phonsayom et al. (2017), who developed embedded system training kits for academic service initiatives in community contexts. Their study identified critical design components and developmental guidelines, reporting that the training kits achieved very high levels of instructional efficiency. This outcome was attributed to the inclusion of embedded system kits that enabled learners to engage directly in authentic, hands-on practice.

Suggestions

1. The educational innovation entitled Embedded System and IoT Learning Skill Training Kit for upper secondary school students was developed to support instructional practices in the subject of Computational Science at Grade 10. Since the content is practice-oriented, its application is considered inappropriate for lecture-based or purely theoretical courses.

2. In order to ensure the effective implementation of the Embedded System and IoT Learning Skill Training Kit for upper secondary school students, schools are required to provide adequate preparation in terms of essential infrastructure. This preparation includes the availability of qualified instructors in Computational Science or computer-related disciplines, as well as access to stable internet connectivity and other necessary facilities.

3. The Embedded System and IoT Learning Skill Training Kit has been designed as a practice-based instructional tool that requires students to engage in hands-on activities. As the kit involves devices that must be connected to electrical power, close supervision, guidance, and monitoring by instructors are required to ensure both safety and the effectiveness of learning outcomes.

4. For future research and the current refinement, the evaluation scope has been expanded beyond E1/E2 efficiency to encompass comprehensive Learning Transformation. By integrating Bloom's Taxonomy and 2025 international assessment standards, the study now evaluates changes across three key domains: cognitive knowledge, psychomotor IoT practical skills, and affective attitudes. This multi-dimensional approach ensures a more authentic reflection of

instructional impact and fosters greater academic confidence in the innovation's holistic educational value.

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