

Transforming Electric Motor Control Labs: Implementing a Cloud Messaging-Based IoT Trainer for Enhanced Engineering Education

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Abstract. This study evaluates an IoT-based trainer for electric motor operation and control in engineering education. Designed with a NodeMCU ESP8266, sensors, and a web monitoring interface, it enables real-time parameter observation. Using a quantitative approach, psychomotor performance was observationally assessed in 20 students across six skills via a Likert rubric. Results showed 60% of students achieved high performance, with a mean score of 21.1/24. Tool preparation was the highest-performing aspect, while sensor data analysis was the lowest. Inter-rater reliability was high ($\kappa = 0.83$). The findings indicate that the IoT trainer significantly enhances practical learning effectiveness and provides industry-relevant experience, offering an innovative solution for developing engineering students' psychomotor skills.

Keywords: Internet of Things, digital trainer, psychomotor skills, engineering education, electric motor.

1 Introduction

Digital transformation in education has become an imperative in the era of the Industrial Revolution 4.0, where technology and connectivity are the primary keys to redesigning learning processes. Technical education, particularly in the field of electrical engineering, is required to adapt swiftly to these developments to prepare graduates who are not only theoretically competent but also possess practical skills relevant to an increasingly digitized industrial world [1]. A critical area within electrical engineering education is learning about the operation and control of electric motors, which form the foundation of modern industrial automation systems. However, this instruction is still often conducted conventionally, utilizing methods and media that have not yet fully accommodated the integration of cutting-edge technologies such as the Internet of Things (IoT).

The primary issue faced in the current electric motor control practicum process is the limitation of training systems capable of simulating real industrial conditions [2].

Conventional trainers often do not allow students to flexibly observe and control the motor system, let alone do so remotely [3][4]. Furthermore, the available trainers generally still rely on direct physical interaction and lack the capability to log operational data or perform real-time cloud-based control [5]. This situation results in suboptimal student comprehension of electric motor control concepts within the context of the real world, which has already adopted network-based automation systems.

If this issue is not promptly addressed, a gap will emerge between technical education curricula and industrial needs. Students will struggle to develop 21st-century competencies such as critical thinking, collaboration, and the ability to leverage digital technologies [6][7]. Furthermore, educational institutions will fall behind in providing contextual, meaningful learning experiences that align with the expectations of a workforce that increasingly relies on IoT-based systems and cloud-based monitoring [8].

To address these challenges, a proposed solution is the development of a learning medium in the form of an IoT-based trainer utilizing cloud messaging, integrating electric motor control concepts with Internet of Things (IoT) technology. This approach enables the remote control and monitoring of the motor system via a cloud-based communication platform, such as the Telegram Bot API, controlled using a NodeMCU ESP8266 microcontroller [9]. Consequently, students can interact with the electric motor control system in real-time, anytime and anywhere, directly from their mobile devices.

The rationale for this approach is robust, grounded in both pedagogical and technological considerations. First, an IoT-based approach creates a more authentic learning environment that closely mirrors actual industrial conditions [8]. Second, the use of cloud platforms like Telegram is proven to be more accessible, lightweight, and does not require the installation of complex additional software, making it highly suitable for educational environments with limited infrastructure [10]. Third, from a cost perspective, this platform is relatively inexpensive yet highly scalable for future development [11].

Furthermore, the development of a cloud messaging-based IoT trainer is a tangible implementation of Project-Based Learning (PBL) and the STEM (Science, Technology, Engineering, and Mathematics) approach. Here, students not only learn theory but are also directly involved in the process of designing, testing, and implementing cutting-edge technology [12][13]. This process directly supports the development of independent, innovative, and systematic thinkers.

The trainer is designed by integrating key components such as a NodeMCU ESP8266 microcontroller, an AC/DC electric motor, a speed sensor, and a Telegram chatbot interface. Telegram was selected due to its Application Programming Interface (API) features that support real-time bidirectional communication, allowing users to control speed, rotation direction, or even shut down the motor remotely via text commands [14]. Leveraging this platform makes the trainer more flexible and responsive to the needs of modern learning, which prioritizes accessibility and active user engagement.

Within the context of higher education, specifically in the Electrical Engineering Education Study Program at Universitas Negeri Medan, the development of such learning media serves not only as a practicum tool but also as part of a sustainable campus digital transformation

strategy. Aligned with the faculty's research and development roadmap, this trainer is a crucial part of efforts to produce adaptive, innovative learning media based on real-world needs [15].

Previous research has demonstrated the effectiveness of IoT-based trainers in enhancing student comprehension. For instance, Firdaus & Aribowo (2022) showed that the integration of IoT in a trainer for the starting and dynamic braking of a 3-phase motor significantly improved the engagement and understanding of vocational high school students [16]. Isnaini et al. (2023) also proved that interactive multimedia and physically developed trainers can enhance university students' learning outcomes and technical skills [5].

However, to date, little research has specifically combined cloud messaging technology like Telegram with electric motor control systems in a higher education context. This study is expected to fill this gap and provide a novel contribution in the form of a more open, adaptive, and contextual learning medium. The adoption of this technology also opens possibilities for further integration with data-driven learning systems, such as student performance monitoring dashboards or even automated assessment systems based on practicum behavior.

Considering these various challenges and opportunities, the development of this cloud messaging-based IoT trainer is viewed as a strategic step that not only addresses the needs of electric motor control practicum but also supports the transformation of electrical engineering education curricula towards a more modern, relevant, and globally competitive direction.

Furthermore, the need for flexible, cost-effective trainers that can represent real-field conditions is increasingly urgent. This aligns with universities' efforts to enhance the quality of technology-based practicum learning, especially in facing the common limitations of equipment, which is often available only in limited quantities and requires high operational costs [1]. Developing IoT-based trainers can significantly reduce technical laboratory operational costs and enable effective distance learning [4].

The implementation of this IoT-based trainer in learning not only provides an alternative solution to these limitations but also offers a more contextual and interactive learning experience for students. Utilizing the NodeMCU ESP8266 module, current and voltage sensors, and a web-based monitoring interface, students can perform real-time monitoring and control of electric motors, both inside and outside the practicum room. The integration of IoT technology in technical education encourages a significant increase in student engagement and the mastery of practical competencies [17][18].

In its implementation, this trainer has been piloted on a limited scale within the Electrical Engineering Education Study Program at Universitas Negeri Medan. The implementation process involved the integration of hardware components, the development of a web-based monitoring interface, and user training for lecturers and students. Initial responses indicated an increase in active student participation in the learning process and a deeper understanding of the working principles of electric motors and their control systems.

Thus, this study aims to provide a comprehensive overview of the implementation steps for the IoT trainer in the practice of electric motor use and control. It is hoped that the results of this implementation can be replicated or further developed by other educational institutions to enhance the quality of technical education, making it relevant to the needs of the digital era.

2 Method

This study employed a quantitative approach with a quasi-experimental one-group pretest-posttest design. The primary objective of this research was to measure the effect of implementing an Internet of Things (IoT)-based trainer on improving students' competency mastery in the Electric Motor Operation and Control course.

2.1 Research Subject and Location

The subjects of this research were 20 sixth-semester students from the Electrical Engineering Education Study Program, Universitas Negeri Medan, who were regularly enrolled in the practical course during the even semester of the 2024/2025 academic year. The subjects were selected using a purposive sampling technique, based on the relevance of their course enrollment and their readiness to use IoT technology. The research was conducted at the Electrical Engineering Laboratory of Universitas Negeri Medan from March to August 2025.

2.2 Research Design and Procedure

This study began with the administration of a pretest to measure students' initial understanding of the basic concepts and fundamental skills in electric motor operation and control. Following this, students participated in practical sessions using the IoT-based trainer for 4 meetings, each lasting 2 hours. The trainer was designed using a NodeMCU ESP8266 microcontroller, current and voltage sensors, and a web-based interface powered by Firebase for real-time monitoring. Upon completion of the practicum, a posttest with equivalent content was administered to evaluate the improvement in student competencies.

2.3 Research Instrument

The primary instrument used in this study was a performance observation rubric designed to assess students' psychomotor skills in operating the IoT-based trainer. This instrument was developed based on the practical competency indicators for the Electric Motor Operation and Control course and referenced Simpson's (1972) psychomotor taxonomy, which includes: perception, set, guided response, mechanism, complex overt response, adaptation, and origination [19].

The observation rubric consisted of 6 performance aspects:

- a) Preparation of tools and materials
- b) Wiring procedures and sensor installation
- c) Operation of the IoT monitoring system (web-based interface)
- d) Measurement of electric motor current and voltage
- e) Analysis of sensor data readings
- f) Work safety and tidiness

The instrument's content validity was confirmed by two expert lecturers in electrical engineering and learning assessment. Reliability was tested using an inter-rater reliability technique, where two independent observers assessed student performance in a preliminary

trial. The reliability coefficient was calculated using Cohen's Kappa formula, yielding a value of 0.81, which indicates a high level of consistency between raters.

2.4 Data Analysis Techniques

Data collected through the performance observation rubric were analyzed quantitatively using descriptive and inferential statistical approaches. Descriptive analysis was conducted to obtain information on the distribution of student performance scores for each psychomotor aspect, including the minimum, maximum, mean, and standard deviation.

Each student received a total score from the 6 performance aspects, with a possible range of 6–24. The scores were then categorized into three levels of proficiency: low, medium, and high, to facilitate the interpretation of learning outcomes.

To ensure scoring objectivity, two independent observers were involved in the assessment process. Consistency between raters was tested using inter-rater reliability analysis with Cohen's Kappa. A coefficient value > 0.75 was considered to indicate high reliability.

If necessary, a correlation analysis between psychomotor aspects was performed to examine the relationship between basic skills (e.g., sensor installation) and advanced skills (e.g., data monitoring analysis).

3 Result and Discussion

3.1 Result

3.1.1 Description of Observation Result

The observation results of student performance regarding the implementation of the Internet of Things (IoT)-based trainer indicate that the majority of students were able to master the targeted work procedures and technical skills. The assessment was conducted on 20 students who participated in three practicum sessions using the designed and tested IoT trainer.

The total score was obtained from the accumulation of six psychomotor assessment aspects, with a possible score range of 6 to 24. Each aspect was rated on a Likert scale of 1 to 4. The analysis results show that the students' mean total score was 21.1, with a highest score of 23, a lowest score of 17, and a standard deviation of 1.5, reflecting a relatively uniform distribution of abilities.

To facilitate the interpretation of the results, the total scores were classified into three performance categories: high (scores 21–24), medium (scores 17–20), and low (scores <17). A total of 60% of the students were in the high category, demonstrating excellent mastery of all trainer operational procedures. 35% were in the medium category, and only 5% were in the low category, indicating a continued need for further guidance in operating the device.

Table 1. Distribution of Student Performance Based on Score Category

Category	Range Score	Respondents	Percentage
High	21-24	12	60%
Middle	12-20	7	35%
Low	<17	1	5%

Based on these results, it can be concluded that the developed IoT trainer has a high level of acceptability and usability among electrical engineering students, both in terms of ease of use, time efficiency, and the functionality of the web-based monitoring system. The low standard deviation value (1.5) also indicates that the variation in performance among students was not extreme, signifying that the teaching approach and practical media used were sufficiently effective across the board.

Furthermore, these findings are reinforced by field documentation and direct observation during the practicum sessions, where students showed high enthusiasm for the new system that facilitates real-time data logging and digital control of the electric motor. Although some technical constraints were still encountered, particularly in understanding the interface and interpreting measurement results, the overall findings indicate that this trainer is viable for adoption in technical practicum activities at both vocational and undergraduate education levels.

3.1.2 Results by Psychomotor Aspect

A further analysis was conducted to examine student performance based on each psychomotor aspect. The assessment of the six aspects provides a detailed picture of the students' strengths and weaknesses in operating the IoT trainer.

Table 2. Average Student Performance Scores per Psychomotor Aspect

Psychomotor Aspect	Max Score	Respondents	SD
Preparation of Tools and Materials	4	3.8	0.4
Wiring and Sensor Installation	4	3.6	0.5
Operation of the IoT Monitoring System	4	3.4	0.6
Measurement of Electric Motor Current and Voltage	4	3.5	0.5
Analysis of Sensor Data	4	3.3	0.7
Safety and Neatness	4	3.5	0.6

Based on the data above, the aspect with the highest score was "Preparation of tools and materials" ($M = 3.8$), indicating that students possessed a strong foundational ability in preparing practical equipment. The aspect with the lowest score was "Analysis of sensor data" ($M = 3.3$), signifying that while technical operation was mastered, students' ability to read and interpret measurement data still requires improvement.

3.1.3 Inter-Rater Reliability Test Results

To ensure the assessment of student performance was objective and consistent, an inter-rater reliability test was conducted using Cohen's Kappa. Two independent observers assessed all subjects based on the same rubric.

Table 3. Reliability Test Results

Observer	Respondents	Kappa Value	Interpretation
1 & 2	20	0.83	Very High

A Kappa value of 0.83 indicates an excellent level of agreement between the two raters. This signifies that the observation instrument has met objectivity standards and that the assessment instructions were well understood by both observers.

3.1.4 Inter-Rater Reliability Test Results

In addition to the quantitative data, several field observations were noted from direct observation and observer notes, which enrich the analysis qualitatively:

a) High Level of Interest in IoT Technology

Students showed significant interest upon learning they could monitor electric motor parameters in real-time via a web device. This increased their active engagement throughout the practicum sessions.

b) Common Errors in the Initial Usage Phase

Several students encountered difficulties with the initial Wi-Fi network configuration, IP address setup, and misreading the current and voltage units on the monitoring interface. These errors gradually improved after technical guidance was provided.

c) Increased Collaboration and Technical Discussion

In group settings, students assisted each other with wiring assembly and sensor data analysis. This indicates that the trainer also successfully fostered social skills and teamwork, in addition to technical skills.

d) Positive Instructor Response to Technology Integration

The supervising instructor stated that the use of this trainer was highly beneficial in bridging theoretical concepts with practical applications, particularly as data visualization helped students understand system responses more easily.

3.2 Discussion

3.2.1 Effectiveness of the IoT Trainer in Supporting Psychomotor Learning

These findings align with previous studies demonstrating that IoT technology can enhance interactivity and engagement in technical learning [4][17]. The trainer used in this study allowed students to monitor current and voltage parameters in real-time via a web interface, thereby creating a learning experience that is more contextual, accurate, and aligned with modern industrial practices.

From the perspective of Simpson's (1972) psychomotor taxonomy, these results indicate that most students have reached the stage of mechanism to complex overt response, where they can perform motor skills with good coordination and a high degree of accuracy. Some students even showed initiative in adjusting tools, reflecting the stage of adaptation [19].

3.2.2 Identification of Strengths and Weaknesses

The psychomotor aspect with the highest score was "Preparation of tools and materials" (M = 3.8), indicating that students' technical readiness was quite mature, both in recognizing tools and assembling them. Conversely, the lowest score was obtained in the aspect of "Analysis of

sensor data readings" ($M = 3.3$). This indicates that students' interpretive abilities remain weaker than their mechanical skills, even though data interpretation is crucial in the context of data-driven decision-making within IoT-based systems.

This finding reinforces studies emphasizing that technology implementation should not be limited to tool mastery but must be accompanied by training in analytical and reflective thinking regarding digital data [6]. Therefore, the integration of higher-order thinking skills (HOTS) approaches in practicums is essential for strengthening students' cognition concerning the data they process [20].

3.2.3 Assessment Feasibility and Reliability

The inter-observer reliability test yielded a Cohen's Kappa value of 0.83, indicating that the assessments were objective and consistent. This strengthens the validity of the results, confirming that student scores were not a product of subjective interpretation but a reflection of actual skills observed systematically.

The success of this reliability test also demonstrates that the observation instrument used was well-standardized and can be replicated in similar studies in other technical education environments.

3.2.4 Pedagogical and Practical Implications

Pedagogically, these results provide evidence that implementing IoT-based practical media can bridge the gap between theory and practice in technical education. The use of a web-based monitoring system not only provides a novel experience for students but also encourages them to actively evaluate system performance visually and digitally [21].

Practically, this trainer has proven to offer a solution to the constraints of conventional laboratory facilities, such as limited measuring instruments, space restrictions, and safety risks. With easily accessible data visualization, students can learn outside the laboratory space without losing a meaningful practical experience [18].

4 Conclusion

This study demonstrates that the implementation of an Internet of Things (IoT)-based trainer in the practical learning of electric motor operation and control significantly contributes to the enhancement of students' psychomotor skills. Through a direct observation-based assessment of six performance aspects, it was found that the majority of students were able to operate the system with a high degree of accuracy, efficiency, and workplace safety. Furthermore, the trainer successfully created a more interactive, modern, and contextual learning experience through its real-time digital monitoring system.

The high inter-observer scoring consistency also indicates that the assessment model employed is reliable and can serve as a reference for evaluating technology-based practical skills. Moreover, these results illustrate that IoT-based practical media are not only pedagogically relevant but also adaptive to the needs and challenges of technical education in the digital era.

The success of this implementation presents broad opportunities for replication and further development, whether in the context of larger classroom scales, across other technical courses, or in the design of curricula oriented toward 21st-century skills. In the long term, the integration of such digital learning systems is expected to bridge the gap between formal education in institutional settings and the evolving skill demands of the industrial world.

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