Utilizing Internet of Things Technology in the Development of AC Electrical Circuit Trainer Module

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Abstract. This research is dedicated to developing an IoT-based AC electrical circuit trainer module to enhance electrical engineering education. The module enables interactive and remote learning, empowering students to access and control AC circuit experiments via IoT-enabled devices. The research follows a systematic design process, beginning with educational needs analysis. It integrates IoT sensors, actuators, and communication protocols into the AC electrical circuit trainer. Experimental studies assess the module's effectiveness by evaluating student engagement, comprehension, and practical skills. Results reveal the IoT-based AC electrical circuit trainer module's potential to significantly improve electrical engineering education. IoT technology's interactive and remote access features encourage self-directed learning and critical thinking, fostering independent exploration and experimentation with AC circuits. This research advances innovative teaching methodologies and underscores IoT's transformative impact on engineering education.

Keywords: AC electrical circuit, Interactive learning, Internet of Things, Trainer module.

1 Introduction

Education is the fundamental foundation for societal development and technological advancement. The current digital era has brought about fundamental changes in how we learn and teach. In this context, the Internet of Things (IoT) technology has played a pivotal role in transforming education to be more adaptive, connected, and responsive to individual needs [1]. IoT provides the capability to integrate physical components with digital systems, paving the way for limitless innovations across various fields, including education. One intriguing breakthrough resulting from IoT is the development of an IoT-enhanced AC Electrical Circuit Trainer Module, which leverages this technology's sophistication to enhance students' understanding in the field of electrical engineering.

In the context of teaching electrical circuits, having a strong theoretical understanding is only a small part of the equation. Practical experimentation and hands-on experience in designing, measuring, and troubleshooting electrical circuits are crucial. The IoT-enhanced AC Electrical Circuit Trainer Module offers an interactive and responsive learning environment, enabling

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students to monitor, control, and collect data from real electrical circuits in real-time [2]. Consequently, electrical engineering education can advance further, preparing students with skills relevant to the ever-changing demands of the industry. This article will detail how the use of IoT technology in the AC electrical circuit training module has shifted the paradigm of teaching and learning in electrical engineering education.

The use of Internet of Things (IoT) technology has permeated various aspects of life, including education. IoT brings forth new opportunities to enhance the learning experience, especially in the context of electrical engineering education. One intriguing implementation is the use of IoT in developing AC electrical circuit training modules. These modules aim to facilitate students' understanding of both the theory and practice of electrical circuits. In this paper, we will discuss how the use of IoT technology can enhance the effectiveness of these training modules.

The utilization of IoT technology in education has shown significant potential in improving students' understanding, accessibility, and data collection efficiency. In the context of AC electrical circuit training modules, IoT enables users to conduct real-time monitoring, access modules remotely, and gather data for further analysis. This research aims to develop an IoT-enhanced AC Electrical Circuit Trainer Module based on the ESP32 electronic development board and evaluate its benefits in the context of electrical engineering education. The study will delve into how the implementation of IoT technology in AC electrical circuit training modules can enrich the learning experience and provide tangible benefits to students. The originality of this research lies in the integration of Internet of Things (IoT) technology with the development of AC electrical circuit training modules.

2. Literature Study

A literature review to support this research has been conducted, including the role of IoT technology in education, the utilization of IoT in electrical circuit practices, the use of the ESP32 electronic development board as the primary IoT component in electrical circuits, and the overall benefits of IoT in electrical engineering education.

2.1 The Role of IoT in Education

The implementation of IoT technology in the field of Education has enabled better accessibility to learning resources. With IoT devices such as tablets, smartphones, and other smart devices, students can access learning materials anytime and anywhere, providing greater flexibility in learning and enabling individualized learning [4-6]. Several other studies have shown that IoT implementation in education allows real-time monitoring of students' learning activities. Connected sensors can collect data on learning behavior, patterns, and students' levels of understanding. This data can be used to identify areas in need of improvement, measure student progress, and provide more accurate feedback to instructors. Thus, IoT implementation in education can enhance monitoring and better analysis [7-8]. Other research indicates that by implementing IoT, learning can be further personalized. IoT-based learning systems can adapt content and difficulty levels to individual student needs, helping students with varying levels of understanding to learn more effectively [9-10].

The use of IoT in education provides students with the opportunity to develop relevant technology skills. They can learn how to operate IoT devices, analyze data, and design technology-based solutions, skills highly valuable in today's job market [11]. IoT enables a more active and practical learning approach. Students can engage in physical experiments using IoT devices, connecting them to real-world aspects such as temperature, humidity, or motion measurements. This allows them to experience the practical applications of the concepts they learn [12]. IoT facilitates better collaboration among students, instructors, and even students from different parts of the world. IoT devices can be used for collaborative projects, and improved connectivity enables more efficient communication in distance learning settings [13].

2.2 The Use of IoT in Electrical Circuit Practice

Specifically, IoT technology is known to be capable of addressing various needs and tasks in electrical circuit practices. IoT can enable more efficient monitoring of electrical circuits. Sensors connected to the IoT network can be used to monitor voltage, current, frequency, and power factor in real-time. This allows electrical technicians to detect potential issues or disruptions more quickly, reducing the risk of equipment damage and unwanted downtime. With IoT, consumers and companies can optimize their energy usage. IoT sensors and devices can assist in monitoring energy consumption and identifying areas where energy efficiency can be improved. This can result in significant energy savings and reduced operational costs. IoT enables smarter load management in electrical systems. By using data from IoT sensors, automation devices can regulate power flow to avoid overloading a circuit or network. This can enhance system reliability and prevent unexpected power outages [14-15].

IoT is also known to be used for predicting maintenance needs in electrical equipment. By continuously monitoring equipment conditions, IoT systems can provide information on when preventive maintenance or replacement of specific components is necessary. This can reduce maintenance costs and extend the equipment's lifespan. In the era of renewable energy, the use of IoT becomes crucial in integrating renewable energy sources into the electrical grid. IoT sensors can assist in monitoring and controlling the production of renewable energy, such as solar panels and wind turbines, to operate optimally [16].

3. Research Methodology

This research will adopt the Research and Development (R&D) method in the development of the Internet of Things (IoT)-enhanced AC Electrical Circuit Trainer Module. This method comprises several stages, namely:

Needs Analysis Stage: The initial step in this research is the needs analysis stage, where the main focus is to understand the needs of students and instructors related to the development of the Internet of Things (IoT)-enhanced AC Electrical Circuit Trainer Module. The first step in this stage is to conduct surveys and interviews with students and instructors in the field of electrical engineering education to identify common difficulties they face in understanding AC electrical circuit materials. Additionally, we will consider their technology proficiency levels and preferences for different learning methods. This needs analysis assists in determining and designing the module with features that meet these needs, thus enhancing student understanding and providing effective support in learning AC electrical circuits using IoT.

Design Stage: The design stage in the development of the IoT-enhanced AC Electrical Circuit Trainer Module will be carried out in detail. First, the module's interface will be designed, taking into account usability, navigation, and information clarity aspects. Next, IoT sensors required to monitor and measure various parameters in AC electrical circuits, such as voltage, current, and frequency, will be identified. Further activities include planning the integration of hardware and software needed to connect these sensors to the IoT platform, such as programming ESP32. During this stage, data security and user privacy will also be considered to protect sensitive information. In this research, we will strive to ensure that the module's design is not only functional but also ergonomic, following principles of good interface design to provide an optimal learning experience for users.

Development Stage: The development stage of the IoT-enhanced AC Electrical Circuit Trainer Module involves several detailed steps, including designing the structure, content, and integrated IoT components. Once the design is completed, the development stage is carried out, where the training module is physically or digitally created according to the established design. Subsequently, this module will undergo a validation stage, where testing in an educational environment is conducted to ensure that the module meets its learning objectives and provides the expected benefits. Finally, after passing the validation stage, the module will be implemented in the electrical engineering education environment, and further evaluation will be conducted to measure its impact and effectiveness in enhancing student understanding and facilitating the learning process.

Validation Stage: This stage is a crucial step in ensuring the effectiveness of the IoT-enhanced AC Electrical Circuit Trainer Module. During this stage, the module will be introduced to a group of students or training participants who represent the actual target users. Throughout the validation process, data collection will be carried out meticulously, including participant monitoring during module usage, collecting responses and feedback from them, and measuring performance in terms of material understanding and the ability to apply AC electrical circuit concepts. The obtained data will be analyzed carefully to evaluate the effectiveness of the module and to identify potential improvements or adjustments that may be needed. The results of this validation will be a critical basis for determining whether the module is ready for broader implementation in education or if further improvements are necessary before wider use.

Implementation Stage: The implementation stage in this research will begin with the deployment of the IoT-enhanced AC Electrical Circuit Trainer Module in the electrical engineering education environment. The module will be integrated into relevant curriculum, and students will be granted access to it. During this stage, instructors and students will receive training related to the use of the enhanced module, including how to utilize IoT features provided. Continuous monitoring of the module's implementation will take place, and data will be collected to evaluate its impact on student understanding, participation, and learning efficiency. The conclusions from this implementation stage will provide insights into the effectiveness and success of the IoT-enhanced training module in improving the quality of electrical engineering education.

The research steps with the R&D method are clearly illustrated in Fig.1.

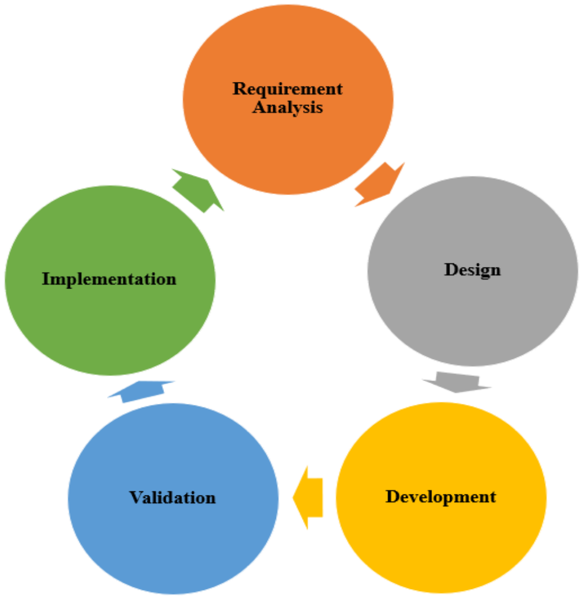

Fig. 1. The stages of research using the R&D (Research and Development) method.

4. Result

As previously explained, this research aims to develop an IoT-enhanced practical module for electrical circuits, which will also undergo validity testing. Therefore, this study resulted in a practical electrical circuit module based on IoT technology, complete with its accompanying guide, as shown in Fig. 2.

Fig. 2. Module and practical guide for electrical circuit.

In accordance with the previously explained R&D research stages, the practical electrical circuit module equipped with IoT technology based on ESP32 was validated with research respondents. A total of 50 respondents participated in this validation process, which meets the research sample requirements as it exceeds the minimum sample size of 30 individuals. The validity testing process involved providing respondents with the opportunity to use the developed practical module, followed by filling out a questionnaire to assess their response to the module. The questionnaire consisted of 11 items to measure the module's suitability. The validity testing process used the corrected item-total correlation parameter with the aim of assessing the suitability of item functions within the overall scale. The validation results of the questionnaire items based on respondent answers are presented in Table 1.

Table 1. Validation test result with corrected item-total correlation.

Question Items	Corrected item-total correlation	Question Items	Corrected item-total correlation
Understanding of the Material	**0.485**	Learning Flexibility	0.704
Accessibility	**0.728**	Satisfaction with Instructor	0.678
Use of IoT Features	**0.797**	Practical Learning Experience	0.530
Effectiveness of Learning	**0.754**	Development of Practical Skills	0.668
Engagement	**0.749**	Recommendation	0.619
Quality of Material	**0.431**		

The validation results for the corrected item-total correlation parameter shown in Table 1 need to be compared to the critical value (r-table) to determine the validity of each questionnaire item. To declare a questionnaire item valid, the corrected item-total correlation value must be greater than the critical value (r-table). The critical value (r-table) for a significance level of 5% (2-tailed) with 50 respondents is known to be 0.28. Based on this value, all questionnaire items are considered "valid" as they have values greater than the critical value (r-table).

In addition to the validity test, this study also conducted a reliability test with a reference Cronbach's alpha value of 0.70. The results of the reliability test are presented in Table 2.

Table 2. Reliability test result.

Cronbach's Alpha	N of Item's
0.905	**11**

Table 2 shows that the Cronbach's alpha value from the reliability test results is 0.905 with a total of 11 questionnaire items. Questionnaire items are considered reliable when the Cronbach's alpha value exceeds the reference value of 0.70. Therefore, the results of the reliability test indicate reliability because the Cronbach's alpha value exceeds 0.70.

The results of the validity test and the reliability test presented in Table 1 and Table 2 indicate that the questionnaire items provided to respondents to validate this electrical circuit lab module are valid and reliable. Thus, it can be concluded that the responses from the respondents to the questionnaire are acceptable. Furthermore, the responses of the 50 respondents to the developed lab module can be observed in the graph presented in Fig. 3.

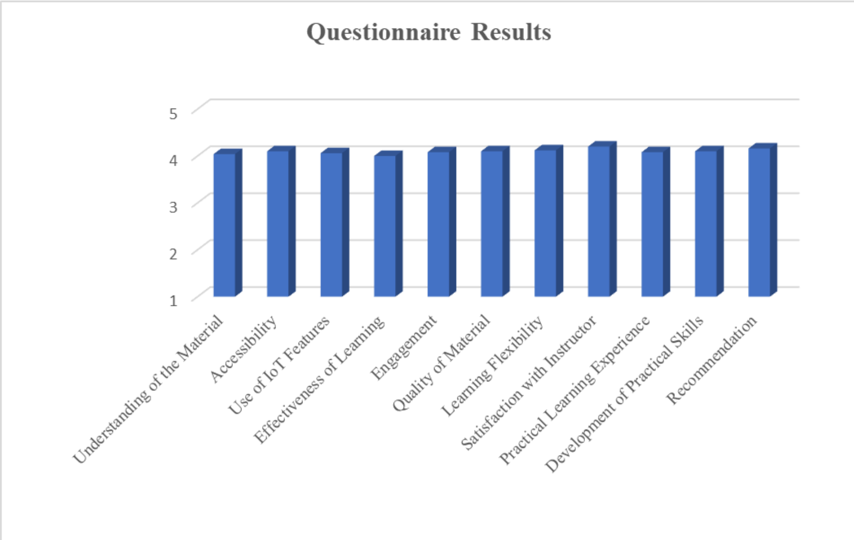

Fig. 3. Usability test results.

Fig. 3 shows that the questionnaire results from 50 respondents have an average value of >4. This value indicates that the electrical circuit laboratory module with IoT falls into the category of "Acceptable".

5. Discussion

This research has produced a prototype for an Internet of Things (IoT) enhanced AC Circuit Laboratory Module. The utilization of IoT technology enhances the functionality of the training module used in learning, while also positively impacting the effectiveness of the learning process. The utility of IoT technology allows for the collection of large amounts of data in a short time frame, in contrast to conventional practical modules where participants have to manually record data, resulting in limited data collection. The ability to gather a substantial amount of data is crucial, especially in the current Industry 4.0 era, which heavily relies on data for obtaining accurate information.

Furthermore, this module provides participants with the opportunity to develop programming skills, which are highly essential in today's technological advancements. The research results align with previous studies that also developed training modules for industrial applications [17]. However, this research includes clear testing regarding the module's suitability as a practical learning tool, whereas previous studies focused solely on system performance. Therefore, this research will provide a clearer understanding for the development of other module types, especially those that make use of IoT technology, by validating the module's effectiveness in the learning process, in addition to testing its functionality.

6. Conclusion

The conclusion of this research indicates that the use of Internet of Things (IoT) technology in the development of the AC Electrical Circuit Trainer Module has had a positive impact on improving students' understanding of AC electrical circuit concepts. The module has also successfully enhanced the accessibility of learning materials, enabled the use of beneficial IoT features such as real-time monitoring, and introduced a more practical learning element. In the context of electrical engineering education, this module offers flexibility in learning, provides a more interactive learning experience, and assists students in developing relevant practical skills. With high levels of satisfaction with the module and strong recommendations from students, this research demonstrates that the use of IoT technology in electrical engineering education can be an effective and acceptable approach to enhancing the quality of learning in the future. Furthermore, this research provides a foundation for further development in the implementation of IoT in electrical engineering education and offers guidance to educational institutions considering the integration of similar technologies into their curricula.

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