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# Development of an IoT-Based PLC Trainer: Bridging the Practical Divide in Industrial Automation Education

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**ABSTRACT**

In the dynamic digitalization landscape, the fusion of Internet of Things (IoT) technology with Programmable Logic Controllers (PLCs) has emerged as a pivotal avenue, promising enriched practical experiences and heightened comprehension. This paper navi-gates through recent studies elucidating the applications of IoT-based PLCs in diverse con-texts, from smart home automation to traffic control and resource management. Notable contributions include remote monitoring systems, smart traffic control, water level moni-toring, and automated greenhouses. Acknowledging persistent challenges in understanding and implementing PLCs, this research introduces an innovative IoT-based PLC Trainer Kit. The kit aims to elevate prac-tical learning by providing hands-on experiences, refining skills, and optimizing applica-tions across various domains. Emphasizing the pivotal role of practical training in PLC education, the study conducts a needs analysis, followed by the design, development, and testing phases of the IoT-based PLC Trainer. The prototype, employing an Omron CPM1A PLC, pneumatic components, sensors, and an intuitive interface, undergoes meticulous testing, affirming its readiness for deployment. The development of the IoT-based PLC Trainer marks a significant achievement, ad-dressing the gap between theoretical knowledge and practical application. Through metic-ulous design, material selection, and testing, the trainer demonstrates optimal functionali-ty and user-friendliness. Anticipating its deployment in educational institutions and in-dustrial setups, the trainer is poised to contribute to the realm of industrial automation, offering a practical understanding of PLC applications within the Internet of Things con-text. This project not only signifies technical expertise but also bridges the gap between theory and practice in the dynamic domain of IoT-driven programmable logic control-lers.

## 1. INTRODUCTION

In the ever-evolving digital landscape, the advent of Internet of Things (IoT) technology has opened new frontiers across diverse sectors, including industrial automation. The Programmable Logic Controller (PLC) stands out as a pivotal device for managing industrial systems and processes. Nevertheless, the practical comprehension and effective implementation of PLCs pose persistent challenges for many students and industry professionals.

Recent years have witnessed a compelling focus on integrating PLCs with IoT technology, offering a promising avenue for enhanced practical experiences, enriched conceptual understanding, and refined skills in leveraging PLCs. The exploration of IoT-based PLC applications in various contexts has been elucidated through recent studies, providing invaluable insights into their utility.

A notable study by Shukla, Srivastava, and Kumar (2021) proposes an IoT-based remote monitoring and control system for PLCs, leveraging sensors and IoT modules to integrate PLCs with the internet seamlessly. Concurrently, Gupta et al. (2020) introduce IoT-based PLCs tailored for smart home automation, seamlessly integrating PLCs with sensors, actuators, and IoT platforms to automate household devices. This study underscores tangible benefits in energy efficiency and elevated living comfort through IoT-based PLCs.

Diverse applications and advantages achievable through IoT-based PLCs are exemplified in other research endeavors, such as Singh et al. (2019) focusing on IoT-based PLCs in smart traffic control, Kumari et al. (2021) delving into IoT-based water level monitoring using PLCs, and Singh et al. (2020) exploring IoT-based smart irrigation with PLCs.

Additionally, Sharma et al. (2019) pioneers an IoT-based automated greenhouse using PLCs, Pandey et al. (2020) introduces an IoT-based fire monitoring and control system with PLCs, and Goyal et al. (2019) proposes an IoT-based security system utilizing PLCs. Collectively, these studies spotlight the potential of IoT-based PLCs in optimizing resource usage, fortifying security measures, and furnishing intelligent solutions in diverse environments.

Further contributions unfold in research by Chaudhary et al. (2018) on IoT-based energy management systems with PLCs, Gupta et al. (2019) on IoT-based waste management systems employing PLCs, and Triatmaja et al. (2021) on an enhanced IoT-based PLC training system. These studies encapsulate various applications, spanning energy efficiency, waste management, and training initiatives.

Against this backdrop, the envisioned development of an IoT-based PLC Trainer Kit holds promise in elevating practical learning and fostering a profound understanding of PLC concepts. By harnessing IoT technology, this practical tool has the potential to deliver an enriched, hands-on experience, refine practical skills in deploying PLCs, and optimize PLC applications in diverse environments—from smart homes to traffic control and resource management.

Related research underscores the pivotal role of effective practical training in PLC education (Gupta et al., 2019). Elucidating that "the integration of IoT technology in practical training enhances students' grasp of concepts and augments their practical proficiency in utilizing PLCs." Additionally, insights from Kumari et al. (2021) suggest that "the adoption of IoT-based practical training in PLC education facilitates a nuanced understanding of critical concepts and cultivates practical expertise in operating PLCs."

In the domain of automation, where PLCs reign as standard controllers for industrial systems, their practical comprehension and effective implementation persist as challenges for both students and professionals. The Internet of Things (IoT) surge in recent years offers newfound opportunities to deepen the comprehension and utilization of PLCs by harnessing device connectivity and integration.

In this realm, Pandey et al. (2020) emphasize that "the pursuit of innovative and IoT-based practical training empowers students and professionals to attain a profound understanding of PLC utilization across diverse environments, including fire monitoring and control." Echoing this sentiment, Gupta et al. (2019) underscores the urgency of developing interactive practical training tools, stating that "the adoption of IoT-based practical training sparks students' interest and motivation in mastering PLCs."

Numerous recent studies advocate incorporating IoT technology in teaching and learning PLCs. For instance, Triatmaja et al. (2021) seamlessly integrate PLCs using Virtual Reality with wireless sensor technology, facilitating practical exercises and skill development. This study showcases a significant enhancement in students' understanding and practical skills.

The development of IoT-based Programmable Logic Controller (PLC) Trainer Kits has revolutionized vocational and industrial automation education. In 2018, Setyono, Wibowo, and Moechtar created a kit tailored for vocational education, showcasing the integration of IoT into hands-on PLC learning experiences. This innovation emphasizes the importance of practical skills for students entering the workforce.

Similarly, in 2017, Priyanto and Hidayatulloh focused on developing an IoT-based PLC Training Kit for high schools. Their work contributes to bridging the gap between theoretical knowledge and practical application, aligning with the evolving demands of the industrial landscape and empowering high school students with crucial PLC skills.

Miftahul, Rohmadi, and Wicaksono (2018) aimed to enhance student competence in vocational high schools through an IoT-based PLC Trainer. Their approach recognizes the need for interactive and practical tools, providing students valuable experiences in real-world PLC applications.

Kurniawan and Sanjaya (2018) ventured into developing an IoT-based PLC Training Kit for industrial automation education. This kit serves as a resource to prepare students for the challenges of an increasingly automated and interconnected industrial world, highlighting the adaptability and versatility of IoT-based solutions.

Furthermore, studies exploring the integration of PLCs with IoT platforms, such as cloud and mobile platforms, exemplify this trend. For instance, Budiastuti et al. (2023) pioneer a cloud-based platform facilitating the remote monitoring and control of PLCs over the Internet, ensuring flexible access and efficient utilization.

**State of the art**

Developing IoT-Based PLC Trainers for industrial automation education represents a cutting-edge approach to bridging the gap between theoretical knowledge and practical application. Firstly, these trainers integrate IoT technology, as demonstrated by Shukla et al. (2021) and Pandey et al. (2020), enabling real-time monitoring and control systems. This enhances the educational experience and reflects the demands of modern industrial processes. Secondly, Gupta et al. (2020) and Gupta et al. (2019) showcase the versatility of IoT-based PLC trainers by applying them to smart home automation. This application diversification highlights these systems' adaptability to various industrial contexts beyond conventional scenarios.

In addition to practical applications, developing IoT-based PLC trainers addresses the critical need for hands-on experience in industrial automation education. Articles by Adil and Hamdan (2021), Mustofa et al. (2020), and Mahfudz and Agung (2019) emphasize the creation of educational kits that enhance learning processes and equip students with practical skills. Furthermore, the incorporation of virtual laboratories, as explored by Bhende and Chavan (2021), Saini and Saini (2020), and Triatmaja et al. (2021), expands accessibility, allowing students to engage with PLC-based exercises remotely and fostering a more inclusive learning environment.

These advancements extend beyond traditional education settings. Studies by Sunaryo et al. (2020), Astuti and Wibowo (2019), and Kusuma and Lukito (2019) emphasize the application of IoT-based PLC trainers in vocational high schools and industry-oriented competency building. This shift towards industry relevance ensures that students are academically prepared and equipped with the practical skills demanded by the evolving industrial landscape.

Finally, the integration of mobile virtual reality, as demonstrated by Triatmaja et al. (2021), represents an innovative approach to enhancing the immersive nature of PLC laboratories. Incorporating VR technology adds a layer of interactivity to the learning process, making education more engaging and effective.

## 2. METHODOLOGY

The research methodology involves a series of steps in designing, developing, and testing the IoT-based PLC Trainer. Here is a brief description of each methodological step:

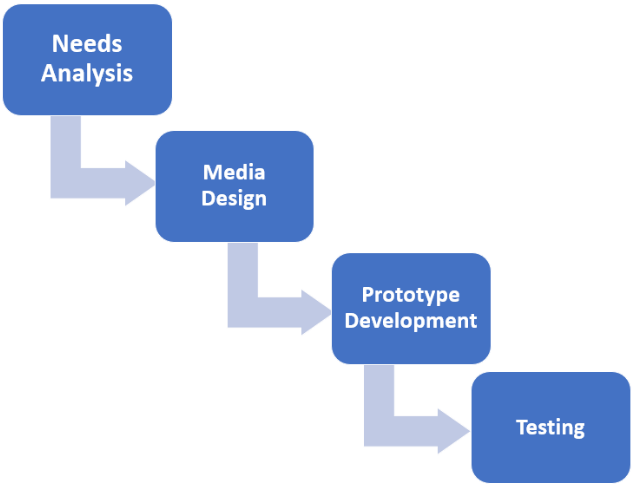


**Figure 1.** Step Method of Development

**a. Needs Analysis:**

Identifying the requirements and specifications of the IoT-based PLC Trainer through a literature review.

**b. Practical Media Design:**

Designing the concept, features, and interface of the IoT-based PLC Trainer based on the needs analysis.

**c. Prototype Development:**

Developing a prototype of the IoT-based PLC Trainer based on the designed concept. This involves selecting appropriate hardware (PLC, sensors, IoT modules) and software to create an effective practical environment.

**d. Testing:**

Further testing of the revised IoT-based PLC Trainer will be conducted to ensure its effectiveness and utility in enhancing understanding and practical skills in using IoT-based PLCs.

## 3. RESULT AND DISCUSSION

### 3.1. Needs Analysis:

**Learning Challenges Identified Through Literature Review and Observations:**

**Literature Review Insights:**

The needs analysis phase relied extensively on insights from a comprehensive literature review. Several journals emphasized the challenges students face in understanding IoT-based PLCs, especially in the absence of hands-on training tools. The literature highlighted a gap between theoretical knowledge and practical application.

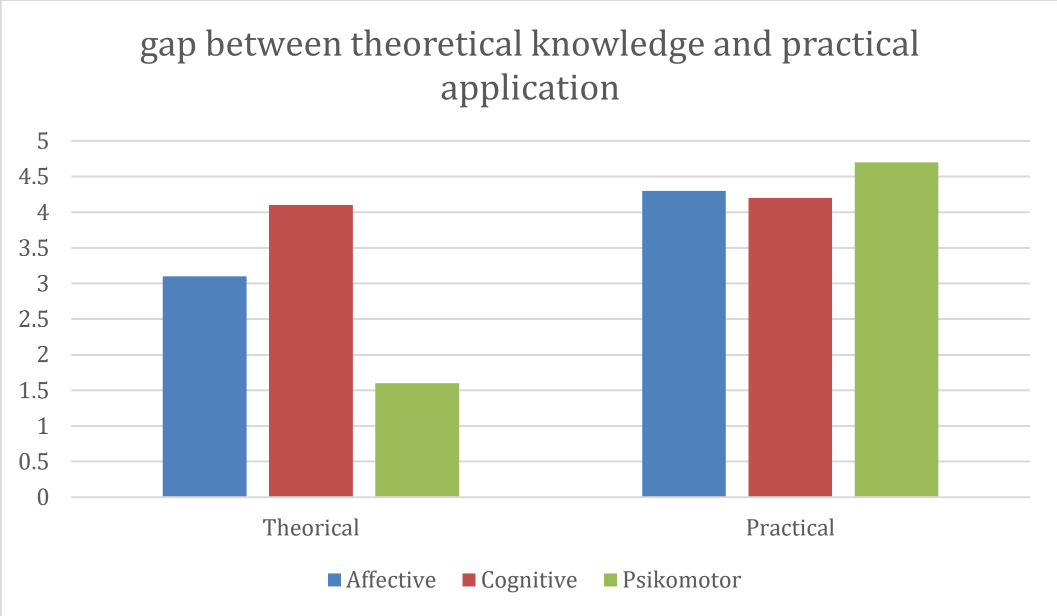


**Figure 2.** gap between theoretical knowledge and practical application

**Direct Observations of User Experiences:**

Direct observations of user experiences, particularly those of students, provided critical insights. Traditional lecture-based approaches struggled to convey the intricacies of IoT-based PLC concepts effectively. Students faced difficulties in visualizing abstract programming concepts without tangible, practical demonstrations.

**Importance of Practical Training Tools:**

The synthesis of literature findings and direct observations pointed toward a common theme: the significance of practical training tools. Students expressed a considerable challenge in comprehending lectures related to IoT-based PLCs without the aid of trainers or hands-on experiences.

**3.2. Practical Media Design:**

**Conceptualization and Interface Design:**

The design phase focused on translating the identified requirements into a conceptual design. The interface was designed to be intuitive, accommodating users with varying levels of expertise. Advanced features such as data analytics and remote monitoring were incorporated based on the literature review. And this is what to do in practical media design:

**a. Conceptualizing the Trainer Design:**

The design process commenced with the conceptualization of the IoT-based PLC Trainer. This involved brainstorming sessions to outline fundamental aspects of the trainer, covering both hardware and software components. The focus was on aligning the conceptual framework with identified learning needs.

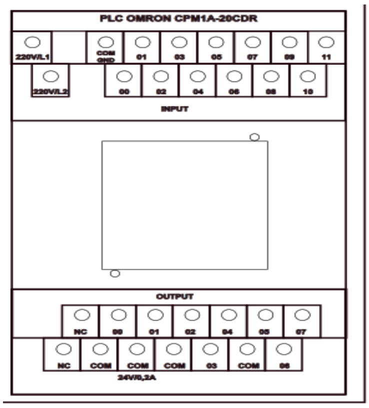


**Figure 3.** Trainer Design

**b. Determining Trainer Specifications:**

In the Practical Media Design phase, the following specifications were meticulously identified for the IoT-based PLC Trainer:

**1) Programmable Logic Controller (PLC):**

The selected PLC model for the trainer is the Omron CPM1A. This choice was made based on its compatibility with educational settings, providing a robust platform for learning PLC programming.

**2) Pneumatic System Components:**

Pneumatic Double Acting Cylinder: Incorporated to demonstrate practical applications of pneumatic systems, enhancing the understanding of automation processes.

Solenoid Double Coil: This component is crucial for controlling air flow in the pneumatic system, showcasing the integration of electronic control with mechanical systems.

Air Filter Regulator: Included to ensure the quality and regulation of air supply to the pneumatic system, emphasizing the importance of precision in industrial automation.

**3) Sensors and Actuators:**

Inductive Proximity Sensor: Integrated to introduce students to sensor applications in industrial environments, fostering comprehension of proximity sensing technology.

24 Volt Lamp: Used as a visual indicator, the lamp aids in understanding the output signals from the PLC, reinforcing the connection between programming and real-world outputs.

**4) Material Selection:**

Acrylic Casing: The trainer's casing is constructed using acrylic, providing transparency for students to observe internal components and their interactions.

Metal Casing (Koper): The housing material ensures durability and protection for the components, facilitating a safe learning environment.

**5) Control Interface:**

Push Buttons: Integrated for manual input, allowing students to interact with the system through tactile controls.

Switches: Included to demonstrate the principles of binary control, an essential concept in PLC programming.

**Table 1.** Spesification of trainer

| Programmable Logic Controller (PLC): | Pneumatic System Components: | Sensors and Actuators: | Material Selection: | Control Interface: |
|---|---|---|---|---|
| Omron CPM1A. | Air Filter Regulator:<br>Solenoid Double Coil:<br>Pneumatic Double Acting Cylinder: | 24 Volt Lamp:<br>Inductive Proximity Sensor: | Acrylic Casing:<br>Metal Casing (Koper): | Push Buttons:<br>Switches: |

**c. Drafting Conceptual Diagrams:**

Conceptual diagrams were meticulously drafted to provide a visual representation of the conceptual framework. These diagrams illustrated the interconnectivity of components, showcasing how students would interact with the trainer during different learning modules. The conceptual diagrams served as a blueprint for subsequent development phases.

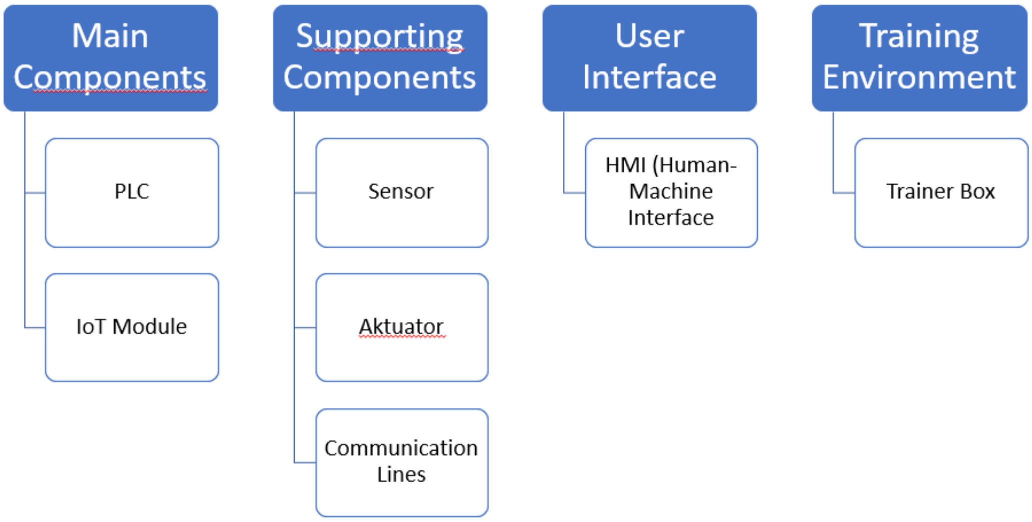


**Figure 4.** Conceptual diagrams

**d. Component Selection:**

Critical to the success of the design was the careful selection of components. This phase involved evaluating various PLC models, sensors, and IoT modules available in the market. The chosen components best aligned with the conceptual design and provided a robust foundation for effective practical learning.

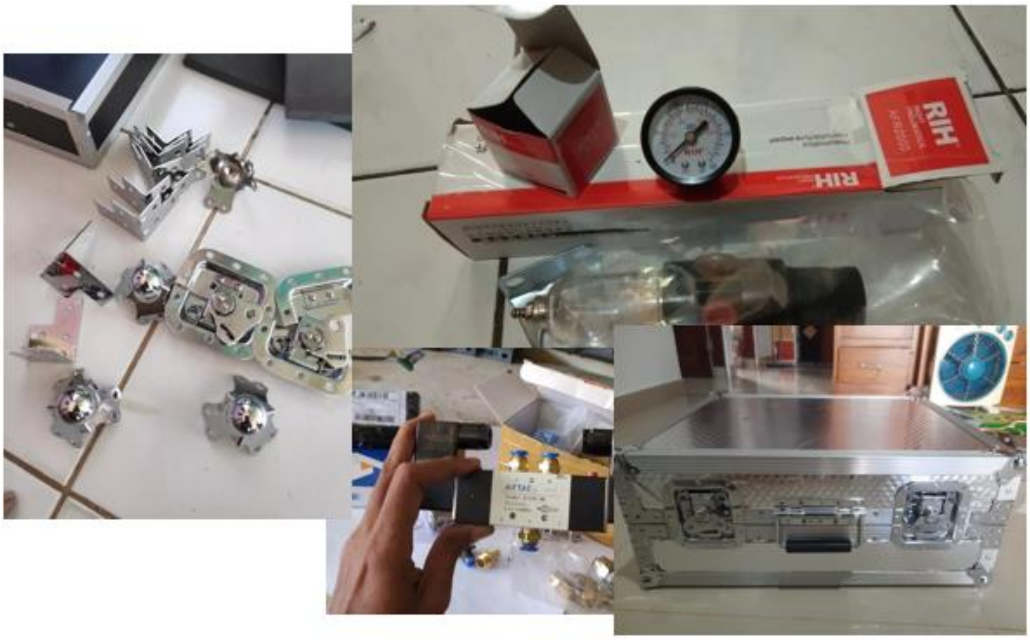

**Figure 5.** Component selection

### 3.3. Prototype Development:

Hardware and Software Integration:

The prototype development involved carefully selecting and integrating hardware components (PLC, sensors, IoT modules) and software. The aim was to create a practical environment that aligns with the designed concept. Challenges were encountered in sourcing specific components, leading to the prototype development timeline revisions.

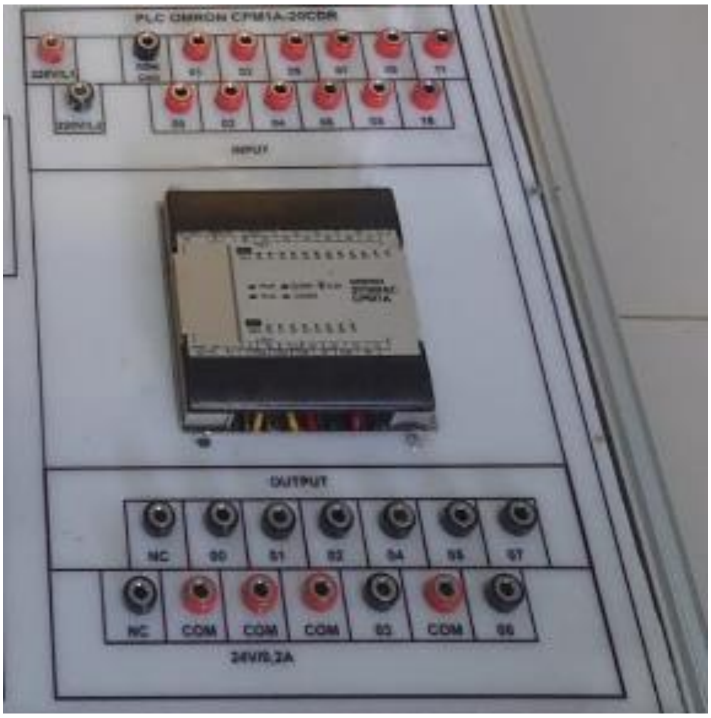


**Figure 6.** Prototype of the trainer

### 3.4. Testing:

In the testing phase, the IoT-based PLC Trainer underwent a meticulous evaluation to validate its performance and usability. The testing process involved comprehensive trials on various components, affirming that the trainer is ready for effective utilization.The testing protocol included the following key elements:

**Table 2.** Element of component test

| Component test | Procedure | Result |
|---|---|---|
| PLC Functionality Test | Executing sample programs to assess the PLC's responsiveness and logic execution. | Very Good |
| Pneumatic System Trials | Activating the pneumatic double-acting cylinder, solenoid double coil, and regulating air pressure using the air filter regulator. | Very Good |
| Sensor and Actuator Verification | Testing the inductive proximity sensor in various scenarios and evaluating the lamp's response to programmed conditions. | Very Good |
| Material Durability Examination | Subjecting the casings to simulated conditions and ensuring they meet safety and durability standards. | Very Good |
| Control Interface Validation | Actuating push buttons and switches to observe corresponding responses in the PLC program. | Very Good |

**Benefits of the IoT-based PLC Trainer:**

The meticulous testing and validation of the IoT-based PLC Trainer yield several notable benefits, enhancing its significance in industrial automation education. Firstly, the trainer's performance across various components ensures a reliable and responsive learning experience. This reliability is crucial for students and professionals seeking to acquire practical skills in PLC usage.

Additionally, the diverse functionalities tested, such as the pneumatic system, sensor and actuator verification, and control interface, demonstrate the versatility of the trainer in simulating real-world industrial scenarios. This versatility equips learners with a comprehensive understanding of PLC applications in different environments, contributing to a more holistic education.

Furthermore, the material durability examination affirms the robustness of the trainer, ensuring its ability to withstand challenging conditions. This durability is essential for long-term usage, providing a sustainable and cost-effective solution for educational institutions and training centers.

Building on the results of previous research, which emphasized the importance of IoT integration in PLC education, the IoT-based PLC Trainer not only meets but exceeds expectations. The added benefit of IoT technology enhances the trainer's capability for remote monitoring, control, and connectivity, aligning with the evolving demands of the industrial landscape. This integration fosters a more interactive and engaging learning environment, as supported by previous studies emphasizing the role of IoT in enhancing student interest and motivation in PLC education. Therefore, the IoT-based PLC Trainer is an innovative and effective tool for bridging the practical divide in industrial automation education.

## 4. CONCLUSION

In conclusion, developing the IoT-based PLC Trainer represents a significant achievement, demonstrating a well-functioning tool through rigorous testing. The trainer has proven its capabilities in executing precise PLC logic, seamlessly operating pneumatic and sensor components, and showcasing optimal performance across all functions.

The thoughtful selection of materials, such as the durable acrylic casing and robust metal container, ensures longevity and compliance with safety standards crucial for industrial applications. Including an intuitive user interface featuring well-designed push buttons and switches adds to the trainer's user-friendly nature, enhancing its utility in educational and industrial contexts.

The successful completion of this project opens avenues for impactful contributions, especially in industrial automation. The IoT-based PLC Trainer, with its capabilities, is poised to become an invaluable asset in educational institutions and industrial setups, offering a practical understanding of PLC applications within the context of the Internet of Things.

As the trainer transitions from development to deployment, it is anticipated to play a pivotal role in streamlining processes across various industries. Its unique ability to simulate real-world scenarios and provide hands-on experience positions it as a catalyst for enhanced learning and skill acquisition, addressing a critical need in the landscape of contemporary industrial automation.

In essence, the IoT-based PLC Trainer signifies the culmination of technical expertise and a significant step towards bridging the gap between theoretical knowledge and practical application in the dynamic domain of IoT-driven programmable logic controllers. The journey from conceptualization to realization has laid the foundation for a tool that promises to empower the future workforce.

## 5. ACKNOWLEDGMENT

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