DESIGN, DEVELOPMENT, AND EVALUATION OF A PROGRAMMABLE LOGIC CONTROLLED ELEVATOR TRAINER AS AN INSTRUCTIONAL AID FOR ELECTRICAL TECHNOLOGY EDUCATION

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ABSTRACT: *Technology education thrives when students are provided with opportunities to connect theoretical knowledge with authentic, hands-on experiences. However, challenges such as limited access to industrial-grade equipment and financial constraints often hinder experiential learning in technical-vocational education (Bakri & Zakaria, 2018; Barrot, 2021). This study presents the design, development, and evaluation of a laboratory-scale Programmable Logic Controlled (PLC) Elevator Trainer intended as a cost-efficient instructional aid for electrical technology education. Guided by a developmental research framework, the project involved the creation of a functional and pedagogically relevant prototype, its construction using locally available materials to ensure affordability and sustainability, and iterative evaluation by subject matter experts, faculty instructors, and students. Results revealed high levels of acceptability in terms of design, usability, and functionality, while student performance in laboratory exercises improved significantly after using the trainer. Beyond its immediate instructional impact, the findings carry broader implications for technical-vocational education and training (TVET), particularly in strengthening curricula for automation and industrial control courses. By demonstrating how locally developed prototypes can deliver measurable learning gains, this study supports institutional and national strategies for affordable technical education and aligns with Industry 4.0 demands, offering higher education institutions a sustainable pathway to bridge classroom theory with industrial practice;[8, 13].*

Keywords: Programmable Logic Controller; Instructional Aid; Prototype Development; Developmental Research; Electrical Technology Education; Automation Education; Industrial Training Systems; Experiential Learning

INTRODUCTION

Experiential learning has long been recognized as central to technology education, particularly when students interact with laboratory equipment that mirrors industrial systems [1,2]. However, financial constraints often limit access to commercial PLC devices, a challenge also noted in vocational settings [5, 7]. To address this challenge, the present study introduces a locally developed PLC Elevator Trainer—a cost-effective instructional tool designed to replicate the operation of an elevator system.

By integrating automation logic, motor control, and PLC programming, the trainer provides authentic laboratory experiences that bridge theoretical knowledge with practical application. This initiative aligns with the competencies required of Bachelor of Science in Electrical Technology students, particularly in courses focused on automation and industrial control systems.

The primary aim of this study was to design, develop, and evaluate a Programmable Logic Controlled (PLC) Elevator Trainer as an instructional aid for electrical technology education. Central to this objective was the creation of a functional and pedagogically relevant prototype that could be effectively utilized in laboratory instruction. To ensure accessibility and sustainability, the trainer was constructed using locally available materials and components, reducing costs without compromising quality. Beyond its technical development, the study sought to determine the trainer's level of acceptability in terms of design, usability, and functionality, as assessed by subject matter experts, faculty instructors, and students. Finally, the research examined the extent to which the trainer enhanced student performance in laboratory exercises, particularly in areas related to automation and PLC programming, thereby validating its role as a meaningful tool for bridging theory and practice in technology education.

RELATED STUDIES

Instructional technology research underscores the importance of laboratory-based tools in bridging theoretical knowledge with practical application. Studies on programmable logic controllers (PLCs) consistently highlight their role in enhancing student competencies in automation and industrial control. For instance, [8] designed and implemented a PLC trainer to support industrial automation education, demonstrating its effectiveness in equipping students with practical skills relevant to Industry 4.0 environments.

Similarly, [9] examined the impact of PLC training kits on creative thinking skills, finding that such instructional devices not only improved programming competencies but also fostered innovation and problem-solving abilities among electrical engineering students. These findings reinforce the pedagogical value of integrating PLC-based trainers into technology curricula.

Beyond PLC systems others [2] developed and evaluated a microcontroller programming trainer, emphasizing that cost-effective prototypes designed with locally available materials can provide sustainable alternatives to expensive commercial devices. Their work supports the notion that locally developed instructional aids can democratize access to advanced technical training.

Recent international studies further extend the relevance of PLC-based instructional aids. Triatmaja [13] developed an IoT-integrated PLC trainer, demonstrating how connectivity features enrich practical learning experiences and prepare students for Industry 4.0 applications. Similarly, Training 4.0 initiatives in PLC education emphasize laboratory setups where components communicate via global data spaces, underscoring the importance of interoperability and smart

automation in modern curricula [11]. These advances highlight the global momentum toward integrating IoT and Industry 4.0 principles into instructional trainers, reinforcing the pedagogical value of the PLC Elevator Trainer introduced in this study.

Collectively, these studies affirm the relevance of the current research, which introduces a PLC Elevator Trainer as a cost-efficient and pedagogically sound instructional tool. By replicating real-world automation systems, the trainer aligns with constructivist learning principles and addresses institutional challenges in providing affordable, hands-on laboratory experiences.

METHODOLOGY

Research Design

This study employed a developmental research design, which is widely used in instructional technology projects to iteratively refine prototypes through planning, design, development, and evaluation [8, 7]. Such designs emphasize continuous feedback from experts and learners to ensure both technical accuracy and pedagogical relevance.

Project Design Description

The PLC Elevator Trainer is a laboratory-scale model simulating elevator operation through automation principles. It integrates electrical and mechanical components for realistic simulation of industrial systems. Key features include:

- Elevator Frame and Car: Driven by a 12V DC geared motor.
- Counterweight Assembly: Provides balance for stable motion.
- Programmable Logic Controller (PLC): Serves as the system's brain for input/output processing.
- Relay Modules and Circuit Breakers: Ensure power control and system protection.
- Power Supplies (12V DC and 24V DC): Provide operational power.
- Control Box and Cable Ducts: Enclose electrical connections for safety.
- Roller Casters: Allow mobility for classroom use.

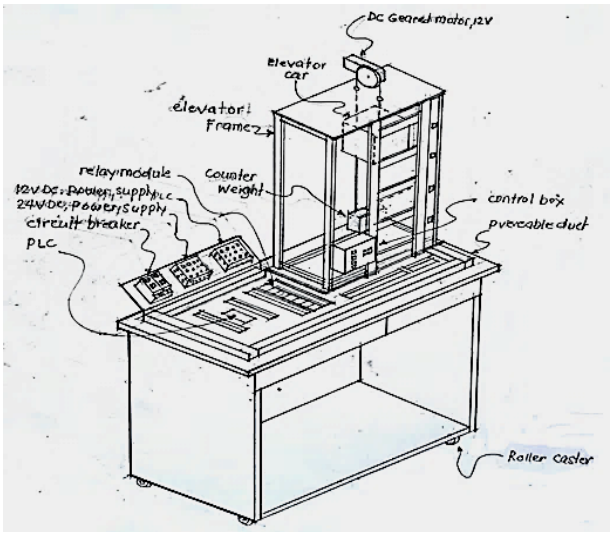


Figure 1: Programmable Logic Controlled Elevator Trainer (Project Design

Sampling Design

Purposive sampling was employed, involving three respondent groups: five subject matter experts, five faculty members, and thirty third-year students. This approach is consistent with prior instructional trainer studies, which often rely on expert validation and targeted student groups to assess usability and learning impact [9, 10].

Data Gathering and Evaluation Instruments

A structured checklist based on a 5-point Likert scale (5 = Excellent; 1 = Poor) was used to assess design, usability, and functionality. Likert-based evaluations are commonly applied in educational technology research to capture perceptions of instructional aids [5, 6] Student performance was measured through pre- and post-laboratory assessments, a method frequently employed to determine learning gains in automation and control courses [3].

RESULTS AND DISCUSSION

Table 1: Summary of Evaluation Results on the PLC Elevator Trainer

Criteria	Experts (n=5)	Instructors (n=5)	Students (n=30)	Overall Mean	Descriptive Rating
Design	4.80	4.75	4.60	4.72	Excellent
Usability	4.70	4.65	4.58	4.64	Excellent
Functionality	4.85	4.70	4.55	4.70	Excellent
Overall Mean	**4.78**	**4.70**	**4.58**	**4.69**	**Excellent**

Scale: 4.50–5.00 = Excellent; 3.50–4.49 = Very Good; 2.50–3.49 = Good; 1.50–2.49 = Fair; 1.00–1.49 = Poor.

Acceptability Evaluation

Evaluation results revealed an overall mean rating of 4.69 (Excellent), indicating that the PLC Elevator Trainer met high standards in design accuracy, usability, and operational performance. Experts highlighted its resemblance to industrial systems, instructors emphasized its instructional efficiency, and students appreciated its intuitive layout and practical demonstration of PLC logic. These findings are consistent with earlier studies that reported strong acceptability of instructional prototypes in technical-vocational education [7, 8] Similar evaluations of PLC training kits have also demonstrated their effectiveness in fostering student engagement and creative problem-solving [9].

Performance Improvement

Students' average post-test scores increased by 22% after using the trainer, confirming its effectiveness in enhancing understanding of automation systems and programming logic. This improvement echoes the outcomes of prior instructional aids that emphasized hands-on engagement, where

experiential learning significantly boosted retention and technical skills ([3, 6]. The combination of real-time simulation and active participation aligns with constructivist learning principles, which stress the importance of authentic interaction in technology education [10].

Comparative Insights

The results of this study reinforce the broader discourse on cost-efficient instructional devices. Locally developed prototypes, such as microcontroller trainers and PLC-based laboratory kits, have been shown to provide sustainable alternatives to expensive commercial systems while maintaining instructional quality [2, 5]. The PLC Elevator Trainer contributes to this body of work by offering a practical, affordable, and pedagogically sound solution tailored to the needs of electrical technology students.

CONCLUSION

The PLC Elevator Trainer demonstrated high acceptability and effectiveness as an instructional aid for electrical technology education. Its locally developed design offers a cost-efficient and pedagogically sound alternative to commercial training systems.

Beyond its immediate instructional impact, the findings carry broader implications for technical-vocational education and training (TVET) policy and curriculum development. By showcasing how locally developed prototypes can deliver measurable learning gains, this study supports institutional strategies aimed at democratizing access to advanced laboratory experiences. Adoption of similar trainers can reduce dependence on costly imported systems, enabling schools and universities to strengthen automation and PLC instruction within limited budgets.

It is recommended that higher education institutions integrate such prototypes into automation and industrial control courses to improve technical competencies and align curricula with Industry 4.0 demands. At the policy level, initiatives that encourage the development and dissemination of locally produced instructional trainers can enhance sustainability, promote innovation, and ensure that TVET programs remain responsive to both national workforce needs and global technological trends.

RECOMMENDATIONS

Based on the findings, it is recommended that higher education institutions integrate locally developed instructional prototypes such as the PLC Elevator Trainer into automation and industrial control courses. Doing so can strengthen laboratory instruction, improve student competencies in PLC programming, and reduce reliance on costly imported training systems.

At the institutional level, curriculum developers should consider embedding prototype-based laboratory experiences into technical-vocational education and training (TVET) programs. This approach ensures that students acquire practical skills aligned with Industry 4.0 demands while maintaining affordability and sustainability.

At the policy level, national education authorities and TVET councils are encouraged to support initiatives that promote the design, development, and dissemination of locally produced instructional trainers. Such strategies can democratize access to advanced laboratory tools, foster innovation among faculty and students, and ensure that technical education remains responsive to both workforce needs and global technological trends.

Future enhancements to the PLC Elevator Trainer may include integration of Human–Machine Interface (HMI) and Internet of Things (IoT) features, which would expand its relevance to smart automation systems and further align instructional practices with emerging industrial standards.

Disclaimer:

To enhance the clarity and scholarly tone of this manuscript, the researcher utilized Generative Artificial Intelligence (Generative AI), specifically OpenAI's ChatGPT, as a language refinement tool. All content, interpretations, and analytical decisions remain the sole responsibility of the researcher and reflect independent academic judgment.

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