The Development of EDU PLC Training Kit for Industrial Automation

Z. Zakaria[1*], H. Jamal[2]
[1]Kolej Teknologi Termaju (ADTEC) JTM, Bukit Katil Campus, 75450, Melaka, Malaysia
[*]corresponding author's email: zamry.z@jtm.gov.my

Abstract – *The high cost and complexity of industrial training equipment often hinder effective technical education, especially in resource-constrained institutions. This paper introduces the Development of EDU PLC Training Kit for Industrial Automation, a cost-effective and portable learning kit designed to provide hands-on training in industrial automation. The system integrates a conveyor mechanism with multiple automation components, including sensors, switches, Raspberry Pi, and a Programmable Logic Controller (PLC). Unlike traditional PLC trainer kits, this solution supports four user and can be accessed through the internet, enhancing flexibility and collaboration. The kit is compatible with various curriculum modules such as PLC programming, mechanical systems, electrical systems, and computer programming (C++, Python, Flow Programming). Its modular design allows easy maintenance and efficient storage, making it ideal for vocational institutes and training centers. The effectiveness of the system was validated through use in mechatronics training sessions and customized industrial courses. The results and positive feedback from students and industry personnel highlight the potential of the EDU Multipurpose Conveyor as a scalable educational tool that supports the goals of Industry 4.0 and Sustainable Development.*

Keywords: *Automation; educational kit; industry 4.0; multipurpose conveyor; PLC training; Raspberry Pi.*

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I. Introduction

Industrial automation is a core area in technical and vocational education because modern manufacturing relies heavily on programmable control, sensors, actuators, data communication, and troubleshooting skills [1]. In many training institutions, however, practical exposure is limited by the cost and maintenance requirements of commercial training systems [2]. Conventional PLC trainers and pneumatic systems are often expensive, fixed in design, and dependent on proprietary components [3]. When a part fails, replacement can be slow or costly, and training sessions may be disrupted. These limitations reduce the amount of meaningful hands-on practice available to students [4].

The EDU PLC Training Kit for Industrial Automation was developed at Institut Latihan Perindustrian (ILP) Tangkak to address these constraints [5]. The project focuses on a modular, portable, and cost-conscious platform that still reflects real industrial practice [6]. The system integrates PLCs, a Raspberry Pi 4, input and output devices, relays, control switches, and a conveyor mechanism on an aluminium profile frame [7]. It also includes wireless access and smartphone-based interaction through Node-RED, allowing the same kit to support local control, remote monitoring, and basic IoT activities [8].

This paper presents the design, implementation, cost analysis, and educational use of the kit. The main objective is to show how one training platform can serve several learning areas, including PLC programming, mechanical and electrical systems, flow-based programming, Python, and C++. The kit is intended not only as a replacement for costly trainers, but also as a flexible teaching aid that can be expanded, repaired, and adapted to future training needs [9].

II. System Design and Features

The Development of EDU PLC Training Kit for Industrial Automation is composed of two main components: a PLC-based control kit and a Raspberry Pie [10]. The control panel integrates programmable logic

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controllers (PLC), a Raspberry Pi 4, relay modules, indicator lights, and a Wi-Fi router. The setup is mounted on an aluminum profile frame, making it compact, portable, and easy to assemble [11].

The system can connect up to four PLC units, which makes it suitable for group-based learning. Components were selected with availability and maintenance in mind, so the kit can be repaired without relying heavily on specialised vendors. Wireless communication is provided through Node-RED, enabling users to monitor system status and control selected functions from a smartphone or browser-based dashboard [12]. This design introduces learners to practical automation while also exposing them to IR 4.0 concepts such as connectivity, data exchange, and remote operation [13].



Fig. 1. Physical layout of the EDU Multipurpose Conveyor training kit design

III. Methodology

The methodology combined hardware assembly, PLC programming, communication setup, dashboard development, and functional testing. The aim was to create a training environment that is close to industrial practice while still being manageable for classroom use [14].

A. Control System Design and Integration

Development began with the configuration of the Siemens S7-1200 PLC using the TIA Portal software environment [15]. Control logic was prepared using standard industrial approaches such as Ladder Diagram, Function Block Diagram, and Sequential Function Chart. These programming methods were selected because they are commonly used in automation training and in industrial maintenance work [16].

After the control logic had been prepared, the conveyor system was assembled and wired to the PLC input and output terminals. Sensors, switches, relays, and actuators were connected using jumper cables to simplify testing and reconfiguration [17]. This arrangement allowed instructors to demonstrate signal mapping, fault finding, and hardware-to-software relationships more clearly during practical sessions.

The PLC was then interfaced with the Raspberry Pi 4 using industrial communication methods such as Modbus TCP/IP, Profinet, and OPC UA [18]. The Raspberry Pi hosted a Node-RED dashboard that allowed users to observe system status and control selected functions over the local network [19]. The dashboard was designed for use with mobile devices, making it easier for students to interact with the system during group activities [20].

The development of the control system began with the design and simulation of the automation logic using ladder diagram programming in the TIA Portal environment. The simulation phase allowed for the identification and rectification of logical errors prior to hardware deployment [21]. Following successful simulation, the validated control logic is deployed to the Programmable Logic Controller (PLC).

Functional testing is then conducted to verify the correctness of control sequences, evaluate system responsiveness, and ensure robust hardware-software integration. The overall control architecture is illustrated in Fig. 2. Block diagram of the control system.

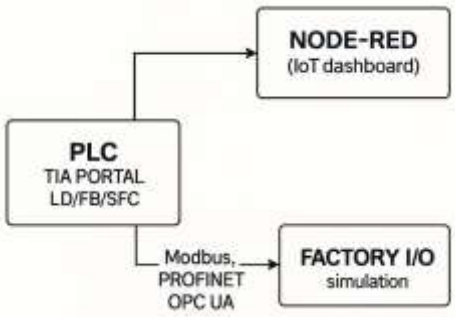


Fig. 2. Block diagram of the control system

B. Cost Analysis

TABLE I
PROJECT COMPONENT COSTS

Component	Cost (RM)
Banana Jack	376.00
PLC Siemens S7 1200	7,200.00
Raspberry Pi 4	355.00
TP-Link ADSL Router	110.00
Other components & Assembly	5,743.00
Total	13,784.00

Table I summarizes the components utilized in the project, with the total development cost amounting to RM13,784. The components include 170 units of Banana Jack costing RM376.00, 4 units of Siemens S7-1200 PLCs priced at RM7,200.00, one Raspberry Pi 4 (8GB) valued at RM355.00, and one TP-Link ADSL Router costing RM110.00. Additionally, other components and assembly expenses account for RM5,743.00. These costs collectively represent the total expenditure for the development of the project.

C. Cost Comparison with Existing Equipment

To evaluate the cost-efficiency of the proposed solution, a comparison was made between the market price of existing conventional training equipment and the cost of deploying the Development of EDU PLC Training Kit for Industrial Automation in a typical technical training setup. Table 2 summarizes the market cost of selected standard training tools.

TABLE II
COST OF CONVENTIONAL TRAINING EQUIPMENT

No	Equipment Description	Estimated Cost (MYR)
1	PLC Training Set (Brand X)	RM26,988.00
2	Laboratory Cabinet and Bench	RM64,468.00

The PLC Training Set (Brand X) represents a dedicated solution for programmable logic controller instruction, often limited to single-system simulation without integration with other automation elements. Meanwhile, the Laboratory Cabinet and Bench serve as general infrastructure for conducting practical sessions but do not contribute directly to automation training outcomes.

In contrast, the Development of EDU PLC Training Kit for Industrial Automation despite not being included in this table offers a consolidated platform that integrates elements from multiple modules such as electrical assembly, pneumatics, and PLC control within a single unit. This not only reduces the need for multiple dedicated training systems but also enhances modularity and flexibility in instructional delivery.

When compared cumulatively, the acquisition of both a branded PLC training set and a laboratory bench setup could cost over RM91,000, whereas the proposed solution provides similar or enhanced functionality at a significantly lower cost. Additionally, the EDU Conveyor system supports a broader range of training modules as shown in Table II, thus improving return on investment and maximizing equipment utilization.

The economic advantage becomes particularly relevant in institutional contexts where budget constraints limit equipment acquisition. By integrating multiple instructional elements into one multipurpose platform, the EDU Conveyor system ensures more efficient resource use, while still fulfilling the technical requirements specified in the MC-091-2/3:2016 standard [22].

From an engineering perspective, the integration of the EDU PLC Training Kit into various learning modules demonstrates its capability as a versatile, multidisciplinary training apparatus for industrial automation. The dataset from 2019 to 2025 shows consistent deployment across ten distinct engineering-related modules, ranging from Electrical and Electronic Assembly to Advanced PLC Programming. Each module recorded identical utilisation frequencies (n = 193 per module; total = 1,930 training engagements), indicating that the system architecture supports diverse technical competencies without substantial reconfiguration.

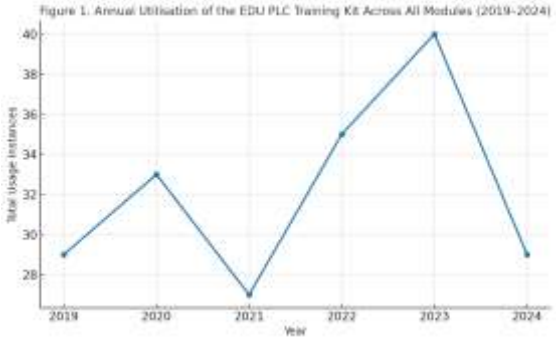


Fig. 3. Annual utilisation of the EDU PLC Training Kit from 2019–2024

IV. Results and Discussion

The EDU PLC Training Kit was deployed across several technical training programmes to assess its usefulness as a teaching and learning tool. Evaluation focused on cost, classroom implementation, student experience, instructor feedback, and institutional benefits.

A. Cost Comparison Results

The cost comparison shows that the EDU PLC Training Kit is substantially cheaper than the reference equipment. At RM13,784.00, the kit costs less than half of the PLC Training Set and about one-fifth of the Laboratory Cabinet and Bench. This difference is important for institutions that need to expand practical training capacity but have limited budgets.

By comparison, the EDU PLC Training Kit for Industrial Automation was produced at a much lower cost of RM13,784.00. This is less than half the price of the Brand X PLC Training Set and about one-fifth of the cost of the Laboratory Cabinet and Bench, as shown in Table III.

This shows that the EDU PLC Training Kit is a more practical and affordable option for institutions that want to upgrade their training laboratories with modern

automation equipment. At the same time, it still provides the necessary functions and remains relevant to current industry requirements.

TABLE III
COST COMPARISON OF PLC TRAINING EQUIPMENT

Equipment Description	Cost (MYR)
PLC Training Set (Brand X)	RM26,988.00
Laboratory Cabinet and Bench	RM64,468.00
EDU PLC Training Kit for Industrial Automation	RM13,784.00

B. Savings Analysis

A comparative cost analysis was conducted to evaluate the financial implications of implementing the EDU PLC Training Kit for Industrial Automation against conventional training equipment. The PLC Training Set (Brand X) is priced at RM26,988.00, while the Laboratory Cabinet and Bench, typically used to support industrial automation training environments, costs RM64,468.00.

In contrast, the EDU PLC Training Kit was developed at a cost of only RM13,784.00. This results in a cost saving of approximately 49% compared to the PLC Training Set (Brand X), and an even greater saving of 79% compared to the Laboratory Cabinet and Bench as shown in Fig3. These substantial reductions in cost highlight the potential of the EDU kit as a highly affordable solution for technical and vocational education institutions.

The savings not only reduce capital expenditure but also make it possible to scale the implementation across multiple training labs or institutions, especially in budget-constrained environments.



Fig. 4. Comparative cost analysis

C. Implementation in Learning Modules (MC-091-2/3:2016)

The EDU PLC Training Kit for Industrial Automation used in the learning module MC-091-2/3:2016 has demonstrated consistent effectiveness from July 2018 until now. Based on the usage data across various modules such as Electrical and Electronic Assembly, Basic PLC Programming, Electrical and Electronic System Assembly, Automation System Calibration, Automation System Maintenance, Advance PLC, and Computer Programming, a stable usage pattern can be observed despite fluctuations from year to year.

The number of students using this training kit was high at the beginning of 2018, around 45 students per module. Although there was a decrease in usage in subsequent years, the usage gradually increased again in recent years, notably in 2023 and 2024. This indicates a sustained interest and need for the training kit to support practical learning for students enrolled in related courses.

The continuous usage proves that the training kit is not only relevant but also adds significant value to the learning process, especially in the fields of automation, electronics, and programming. This success also shows that the training kit can support the implementation of a dynamic curriculum that meets the evolving demands of the industry.

Overall, the usage data shows that the training kit has been effective in helping students connect theory with hands-on practice. It has also supported the development of important technical skills, helping students meet the learning outcomes of the modules.

Table IV presents the implementation of the training kit across the different modules and shows the number of students who used the system each semester.

TABLE IV
MODULE-WISE IMPLEMENTATION

MODUL	2/2018	2/2019	1/2020	2/2020	1/2021	1/2022	2/2022	1/2023	2/2023	1/2024	2/2024	1/2025
B10-31-22 ELECTRICAL AND ELECTRONIC ASSEMBLY	45	29	13	20	16	11	25	10	24	16	22	7
B10-31-25 BASIC PLC PROGRAMMING	45	29	13	20	16	11	25	10	24	16	22	7
B10-32-22 ELECTRICAL AND ELECTRONIC SYSTEM ASSEMBLY	45	29	13	20	16	11	25	10	24	16	22	7
B10-32-24 AUTOMATION SYSTEM CALIBRATION	45	29	13	20	16	11	25	10	24	16	22	7
B10-33-21 AUTOMATION SYSTEM MAINTENANCE	45	29	13	20	16	11	25	10	24	16	22	7
B1033-23 ADVANCE PLC	45	29	13	20	16	11	25	10	24	16	22	7
B10-23-26 COMPUTER PROGRAMMING	45	29	13	20	16	11	25	10	24	16	22	7

D. Educational Impact

Before the introduction of the EDU kit, practical training at ILP Tangkak was constrained by the limited number of pneumatic trainers available for a class of about 30 students. This situation reduced individual practice time and sometimes caused delays during practical lessons. The EDU kit helped increase training access by allowing more students to work simultaneously and by supporting repeated practice across several modules.

Because the system links mechanical movement, electrical wiring, PLC control, network communication, and dashboard operation, students are able to connect theory with real troubleshooting situations. This is especially valuable in mechatronics and industrial automation, where technicians are expected to understand how different parts of a system interact.

E. User Experience and Feedback

Students reported that the kit helped them understand automation concepts more clearly because they could practise with real components rather than relying only on classroom explanation or simulation. Instructors also found the system easier to schedule and manage compared with older, less flexible equipment. During customised training courses, industry partners such as ST Microelectronics and Micron Malaysia gave positive feedback on the kit because its functions were relevant to current industrial training needs [23].

F. Institutional Benefits

The kit reduces dependence on external maintenance support because many of its components are accessible and replaceable. It also lowers the cost of future expansion, since additional kits can be built at a lower price than purchasing conventional equipment. At the institutional level, the project supports IR 4.0 training, promotes sustainable use of resources, and strengthens practical delivery in competency-based programmes.

G. Educational Engineering

From an educational engineering perspective, the kit supports outcome-based learning by encouraging students to design, program, test, evaluate, and improve their work. These repeated cycles mirror the way automation systems are developed and maintained in industry. As a result, learners gain not only technical knowledge, but also a practical problem-solving mindset that is important in modern manufacturing environments.

V. Conclusion

The EDU PLC Training Kit for Industrial Automation provides a practical and affordable approach to improving automation training in technical and vocational institutions. By combining PLC control, a conveyor mechanism, Raspberry Pi-based communication, Node-RED monitoring, and modular construction, the system addresses several limitations of conventional training equipment, including high cost, limited scalability, and complex maintenance.

The kit not only reduces training equipment costs by more than 50% but also enhances training flexibility through features such as multi-user support, Wi-Fi connectivity, and smartphone-based control via the Node-RED platform. Its application spans multiple disciplines, supporting learning modules in PLC programming, electrical and mechanical systems, and modern computing languages such as Python and C++. The portability and ease of use also ensure that students receive more frequent, individualized hands-on training an essential factor in skill mastery and industry readiness.

Successful deployment in real classroom environments, as well as its positive reception in industrial short courses and training collaborations, underscores the kit's relevance and adaptability. Furthermore, feedback from instructors, students, and industry stakeholders confirms the EDU kit's potential as a scalable, future-oriented solution for enhancing mechatronics and automation education.

As institutions increasingly aim to align with the demands of the Fourth Industrial Revolution (IR 4.0), innovations such as the EDU Multipurpose Conveyor offer a sustainable pathway forward ensuring that both teaching and learning remain responsive, accessible, and technologically current [24].

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VII. Conflict of Interest

The authors declare no conflict of interest in the publication of this research.

VIII. Author Contributions

Z. Zakaria: Supervision, manuscript preparation, testing, data analysis and evaluation; H. Jamal: System design and hardware integration.

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