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Design and Development of a Programmable Logic Controller (PLC) Trainer Kit as a Practical Support Tool for the Programmable Logic Control Course

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Abstract

The rapid development of modern industries increasingly relies on automation systems to improve product quality, shorten production time, and reduce human labor costs. One of the technologies used in automation systems is the Programmable Logic Controller (PLC), which has replaced conventional control systems. To meet industry demands, students in the Electrical Engineering Education Program at Universitas Negeri Jakarta (UNJ) are expected to have skills in operating and programming PLCs. However, based on observations, students' understanding of PLC materials remains low, and the laboratory's supporting facilities for PLC learning are still limited. This research aims to develop a PLC Trainer Kit and its corresponding Jobsheet as a Practicum Support Tool in the Programmable Logic Control course. The development method used is Research and Development (R&D) with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The research results show that the developed PLC Trainer Kit obtained a feasibility score of 97.3% from material experts, 89% from media experts, and 94% from student trials. Thus, it can be concluded that this PLC Trainer Kit is highly suitable as a learning aid in the Electrical Engineering Education Program at UNJ. This study is expected to contribute to improving students' understanding of PLCs and facilitating more interactive and applicable learning.

Keywords: practical support tool, programable logic controller (PLC), trainer kit

Introduction

The current industrial society environment, which is increasingly reliant on automation, forces sectors to adopt advanced technology (Yousif et al., 2024). Automation technology refers to control systems that enable machines to operate independently, without human assistance (Raju et al., 2024). In the industry, there is a high demand for automation systems to ensure the quality of manufactured goods, reduce the time required for production, and lower the costs associated with labor (Sobottka et al., 2024). The growth of science and technology during this ongoing period of globalization motivates Indonesia, recognized as a developing country in ASEAN, to enhance its competitive advantage over other countries (Amornkitvikai & Charoenrat, 2024). This phenomenon of globalization has significantly impacted various fields, especially the education sector in Indonesia.Education plays a crucial role in producing high-quality human resources (Bastian, 2024).

The quality of graduates cannot be separated from the role of higher education institutions during the educational period (Chikazinga, 2024). The use of learning media is considered very supportive in enhancing students' competencies (Koka, 2024). With the advancement of science and technology in the industrial sector, there has been a transition from traditional relay-based control systems to digital control systems using Programmable Logic Controllers (PLC) (Beňo et al., 2024). Over the years, PLCs have been used in electrical settings due to their enhanced features.PLC-based control systems are used for various purposes, such as load shedding, monitoring electrical installations, fault identification, and more (Guibout et al., 2024). The advantages of PLC compared to other control systems include flexibility, more economical costs, speed, reliability, ease of programming, safety, and ease of modification and error correction (Liu et al., 2024).

Currently, the industry has abandoned conventional control systems and fully switched to PLC. Therefore, learning PLC has become important for students to master in order to meet the needs of the industrial world. Electrical engineering students, for example, are required to understand PLCs due to their increasing use in the industrial sector (Han, 2024). They are expected to be able to read and understand programs, comprehend the working process of a system, as well as operate and modify PLCs (Liu, 2024). At an advanced level, they are also expected to be able to create programs from the work description of a system and apply them in troubleshooting.

The creation of PLC programs supported by simulators or prototypes for testing the programs can provide a deeper understanding of the basic principles of PLC operation and programming (Yao et al., 2024). Therefore, educational institutions must equip students with the essential knowledge and skills to face the challenges of a rapidly changing world (Ul Hassan et al., 2024). Quality education is the key to producing quality graduates.As an effort to enhance students' understanding of PLC, an effective learning medium is needed. Learning media can enhance students' active participation because it serves as a bridge between lecturers and students (Bergdahl et al., 2024; Picton & Baik, 2024).

In the Electrical Engineering Education Study Program at Jakarta State University, the course that focuses on PLC is the Programmable Logic Control course. In this course, students study various materials, such as sequential control, PLC devices, PLC programming, timer functions, counter functions, arithmetic comparison operations, analog input, and simple control applications. According to the findings from the assessment conducted through observation, interviews, and surveys sent to students from the 2020, 2021, and 2022 batches of the Electrical Engineering Education Study Program at Universitas Negeri Jakarta, the level of students' understanding of PLC material shows that 60% are less knowledgeable and 30% are moderately knowledgeable.Regarding the obstacles faced by students, 85% of respondents attributed it to the limited availability of practical tools.

Based on observations in September 2024, the Electrical Engineering Laboratory only has one PLC Trainer Kit.This indicates a lack of learning media facilities, considering the importance of such equipment as a learning medium.The provision of supporting tools, such as PLC trainers, is crucial because they can help clarify the delivery of material, enhance students' understanding, and streamline the learning process. In response to the above, this research attempts to find a solution by designing a Programmable Logic Controller (PLC) Trainer Kit and its Practical Jobsheet as supporting tools for the laboratory sessions in the programmable logic control course.In this research, testing of the performance of the designed tool was also conducted.

Methods

The approach taken in the study of the development of the Trainer Kit for Programmable Logic Controllers (PLC) as an educational tool in the Programmed Logic Control Course is the research and development methodology, also known as Research and Development (R&D). The development research technique is a method used to create a specific product. The R&D research method is conducted to obtain responses (qualitative) or test the effectiveness (quantitative) of a produced product (Sugiyono, 2019). Considering this, it is expected that this research approach will produce a product that will find widespread use and utility in society, particularly in the field of education.

This study uses a research approach that combines one of the R&D development frameworks known as the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation.The goal is to create a learning resource for a practical trainer for a Programmable Logic Controller, organized in incremental phases. The implementation of this research follows the specified stages outlined in the ADDIE framework.

The ADDIE model was introduced in the 1990s and created by Raiser and Mollenda.It serves as a reference for creating an effective, adaptable, and supportive educational program infrastructure that enhances the learning experience. The ADDIE learning design framework consists of five direct phases that guide its implementation.As its name suggests, the ADDIE model encompasses five distinct phases in the learning process.

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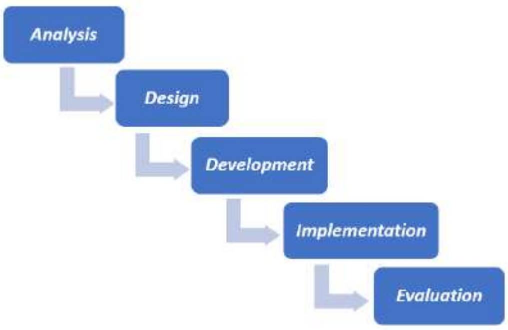

Figure 1. Steps of the ADDIE development model

This model suggests five stages, specifically:

1. The first step, Analysis, involves examining the requirements in the educational process to identify problems and accurate solutions while assessing student competencies.
2. The second step, Design, focuses on determining unique competencies, techniques, educational resources, and learning strategies.
3. The third step, Development, requires the creation of programs and teaching resources intended for use in the educational program.
4. The fourth step, Implementation, involves the execution of the educational program by applying the outlined design or specifications.
5. The final step, Evaluation, consists of assessing the educational program and learning outcomes.

The research to be conducted is the design of supporting facilities for the Trainer Kit programmable logic controller practicum in the programmable logic control course of the electrical engineering education study program at Universitas Negeri Jakarta.This design involves the development of a Trainer Kit equipped with a guide module for using the Trainer learning media, accompanied by practical learning activities.

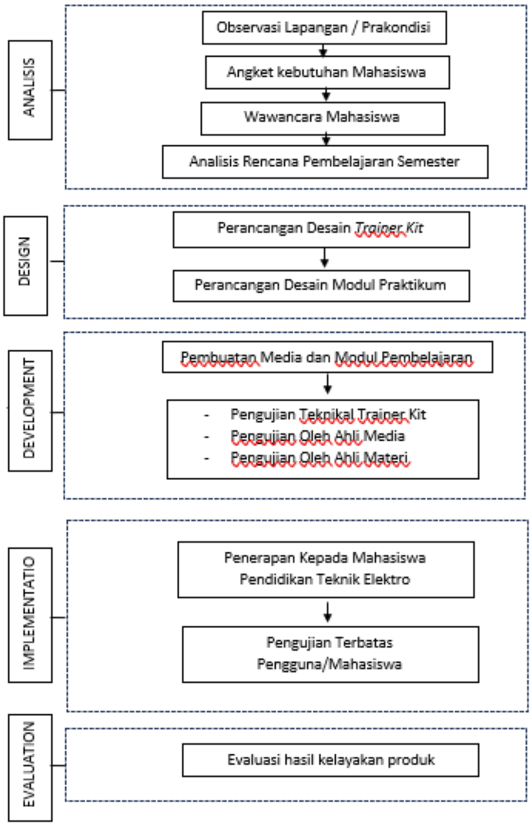

Figure 2. Research Flow Diagram

Data Collection Techniques

The data collection techniques used in this research are interviews and questionnaires.Interviews and questionnaires are used in the process of analyzing needs, student characteristics, and student responses. The data collection techniques are described in Table 1.

Table 1. Data Collection Techniques

No	Data	Data Collection Techniques
1	Observation	Precondition Observation with direct observation in the PLC Practicum laboratory to obtain qualitative data.
2	Student Needs Questionnaire	Structured questionnaires via Google Forms, filled out by students who have taken the Programmable Logic Control course to obtain qualitative data.
3	Student Interviews	Structured interviews with students who have taken the Programmable Logic Control course to obtain qualitative data.
4	Technical Testing	Component function test sheet to obtain quantitative data.

No	Data	Data Collection Techniques
5	Testing by media experts and subject matter experts	The testing sheets for Media Experts and Material Experts are given to validator lecturers in their respective fields to obtain quantitative data.
6	Analysis of user responses to learning media	Structured questionnaires given to students who have used the developed product to obtain quantitative data.

Data Collection Techniques

The data analysis technique that will be used is qualitative descriptive, which involves presenting the media product designed after its implementation in the form of a finished product and testing the product's feasibility. After the data is obtained, the next step is to convert the qualitative data into quantitative data using a Likert scale with a 5-point rating. From the responses obtained to see the weight of each response and calculate the percentage score written with the following formula:

$$Eligibility\ Percentage\ (\%) = \frac{The\ observed\ score}{Expected\ score}\ X\ 100\%$$

If the average percentage value has been obtained, the next step is to assign a quality predicate to the product based on the Rating Scale measurement scale. The Rating Scale designation scale is the conversion of qualitative data into quantitative.

Table 2. Feasibility Assessment Scale

No	Score in Percentage (%)	Eligibility Category
1	81% < X ≤ 100%	Very Feasible
2	61% < X ≤ 80%	Feasible
3	41% < X ≤ 60%	Feasible Enough
4	21% < X ≤ 40%	Not Feasible
5	0% < X ≤ 20%	Very not Feasible

Results and Discussion

This research was conducted to create an educational media, the Trainer Kit Programmable Logic Controller (PLC), to be used in programmable logic control classes. The research and development process follows the ADDIE model, which includes five phases: Analysis, Design, Development, Implementation, and Evaluation. Below are the findings related to the creation of educational media for the Trainer Kit Programmable Logic Controller (PLC) that utilizes the ADDIE framework for the programmable logic control course. Context: Below are the findings related to the creation of educational media for the Trainer Kit Programmable Logic Controller (PLC) using the ADDIE framework for the programmable logic control course.

Analysis Stage

The initial stage that occurs is the analysis stage.During this stage, some initial planning was carried out to create a Trainer Kit for the Programmable Logic Controller (PLC) learning material.This planning is divided into 3 stages, namely Observation, Student Needs Questionnaire, and direct interviews with students who have registered or are currently participating in the Programmable Logic Control Practicum class. The planning is divided into 3 stages: Observation, Student Needs Questionnaire, and direct interviews with students who have registered or are currently participating in the Programmable Logic Control Practicum class.

Design Phase

Based on the results obtained from the analysis stage.This learning media includes the Programmable Logic Controller (PLC) Trainer Kit and the Programmable Logic Controller (PLC) practical jobsheet.

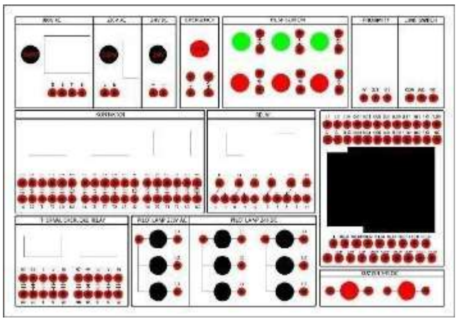

Figure 3. Component Layout

The Trainer design was made portable based on the suggestions and feedback from students in the analysis of the student needs questionnaire shown in Figure 4.In the analysis data, 85% of students rated or preferred the portable practical tool in the form of a hardcase, making it more flexible and easier to carry.In this Trainer design, a hardcase was created as a place for all the components. In Figure 4 and 5, the design of the Programmable Logic Controller (PLC) Trainer Kit was created using Adobe Photoshop and Sketchup software. The dimensions of the Trainer are 400 mm x 600 mm x 210 mm, made of teak wood and acrylic. Here is the 3D view of the design for the Programmable Logic Controller (PLC) Trainer Kit.

Figure 4. Box Trainer Kit Design

Figure 5. Internal Design of the Trainer Kit

In Figure 6. The design of the practical jobsheet was carried out using Adobe Photoshop, Canva, and Microsoft Word software.

Figure 6. Practical Work Jobsheet Cover Design

Development Stage

Actions carried out during this stage include product production, technical evaluation, and product validation. This product undergoes two types of validation: one by subject matter specialists and the other by media specialists.

Creation of Trainer Kit

Creation of the Component Layout Frame

In Figure 7, the component layout is made using 6mm thick acrylic material covered with a component layout sticker with dimensions of 375 mm x 540 mm.then the component layout frame is made using 1.5mm x 1.5mm hollow steel. Here is the image of the component layout frame construction.

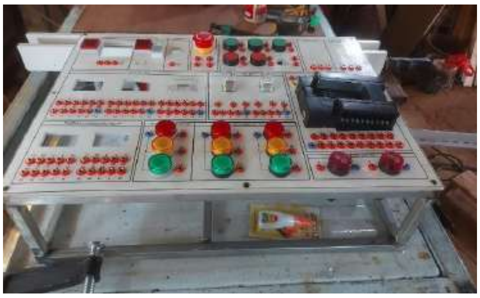

Figure 7. Creation of Component Layout Framework

Cable Installation

In Figure 8, the stage of installing each component pin is shown, connecting to the female banana plug port according to the designed label.The cables used are AWG 0.8mm for DC voltage, NYAF 1.5mm for 1-phase voltage, and NYAF 2.5mm for 3-phase voltage. Here is the image of the component pin wiring.

Figure 8. Cable Installation

Box Construction

In Figure 9, the box is made using a base of Dutch teak wood with a thickness of 20 mm, coated with melamine and an aluminum frame, equipped with a handle and lock. The dimensions of the box on the trainer are 400mm x 600mm x 210mm.Here are the images of the process and the result of making the Trainer kit box.

Figure 9. Box Construction

In picture 10, it is the final result of the programmable logic controller trainer kit creation.

Figure 10. Final Results of Trainer Development

Technical Testing

Technical testing is conducted to evaluate the performance of each component in the learning media, in order to ensure its conformity with the product design.This test aims to evaluate the manufacturing results of each component. The results of the component testing can be seen in Figure 11 below.

Pengujian Teknikal																	
Nomor Butir																	Jumlah
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Total Skor																	**17**
Persentase Kelayakan (%) $= \frac{\text{Jumlah Skor yang di dapat}}{\text{Jumlah skor maksimal}} \times 100 =$ $= \frac{17}{17} \times 100 = 100\ \%$																	100 %

Figure 11. Technical Testing Results

Based on the assessment data from the technical testing shown in Figure 11 with an average percentage value of 100%, the components in the Trainer Kit are declared very suitable for use and classified as excellent. Based on the assessment data from the technical testing shown in Figure 11 with an average percentage value of 100%, the components in the Trainer Kit are declared very suitable for use and classified as excellent.

Media Expert Testing

The assessment by media experts includes technical and aesthetic/visual aspects.The technical aspect includes 11 evaluation items representing 4 indicators, namely (a) items 1-3 represent the indicator of tool quality, (b) items 4-6 represent the indicator of tool safety, (c) items 7-9 represent the indicator of tool usefulness, (d) items 10-11 represent the indicator of tool ease of use. In the aesthetic/appearance aspect, it contains 8 assessment items representing 3 indicators, namely (a) items 12-14 contain indicators of display quality, (b) items 15-17 contain indicators of readability, and (c) items 18-20 contain indicators of neatness.The data from the media expert validation can be seen in Figure 12 as follows.

Ahli	Aspek		Jumlah
	Teknis	Tampilan	
Ahli Media	48	41	89
Total skor			**89**
Persentase Kelayakan (%) $= \frac{\text{Jumlah Skor yang di dapat}}{\text{Jumlah skor maksimal}} x\ 100 =$ $= \frac{89}{100} x\ 100 = 89\ \%$			89%

Figure 12. Results of Media Expert Testing

Based on the assessment data from the questionnaire given to media experts shown in Figure 12, with an average percentage score of 89%, the Trainer Kit product is declared very suitable for use in learning.

Testing by Subject Matter Experts

Assessment by subject matter experts includes educational/material aspects. The aspect includes 15 assessment items that represent 5 indicators.The distribution of the assessment items is as follows: (a) items 1-4 contain indicators of alignment with the syllabus, (b) items 5-7 contain indicators of the completeness of the presented material, (c) items 8-10 contain indicators of learning media that encourage student creativity, (d) items 11-13 contain indicators of the Trainer providing learning opportunities, (e) items 14-15 contain indicators of the Trainer's alignment with the students' cognitive abilities.Here are the data results of the feasibility test validation by subject matter experts.

Aspek Edukatif																
Ahli	Nomor Butir															Jumlah
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Ahli Materi	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	73
Total Skor																**73**
Persentase Kelayakan (%) $= \frac{\text{Jumlah Skor yang di dapat}}{\text{Jumlah skor maksimal}} x\ 100 =$ $= \frac{73}{75} x\ 100 = 97{,}3\ \%$																97,3 %

Figure 12. Results of Media Expert Testing

Based on the assessment data from the questionnaire given to media experts shown in Figure 12, with an average percentage score of 89%, the Trainer Kit product is declared very suitable for use in learning.

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Respon Pengguna	Aspek Teknis	Aspek Tampilan	Aspek Edukatif
Skor Setiap Aspek	2394	1960	1142
Skor Keseluruhan	5496		
Persentase Setiap Aspek	93%	93%	97%
Persentase Keseluruhan	94%		
Kriteria	**Sangat Baik**		

Figure 14. User Testing Results

Based on Figure 14, in the technical aspect, there are 11 indicators that are being evaluated.The assessment of each indicator has a very good rating, which is above 90%. The overall assessment of the technical aspect is 93%.Therefore, it can be concluded that the Trainer Kit Programmable Logic Controller (PLC) learning media has a very good response to technical aspects. Context: It can be concluded that the Trainer Kit Programmable Logic Controller (PLC) learning media has a very good response to technical aspects.

Evaluation Stage

The purpose of the evaluation is to improve the final product based on the assessments and opinions of media experts, subject matter experts, and learners provided during the implementation phase. Here is the Evaluation based on each expert.

Evaluation by Media and Content Experts

Here are the points obtained based on the suggestions from media experts.

1. Give color labels to distinguish between AC and DC voltage components.
2. Complete the Current Limit Information on the components
3. Complete the use of K3

4. Pay attention to the loose port

In the Expert's Material, there are no repair notes, so the practical job sheet is deemed very suitable for use.

The results of this study indicate that the PLC trainer kit developed as a practical support tool for the Programmable Logic Control course is highly feasible for use in the learning process. The assessment data show that the product received a high eligibility score across various aspects, including content quality, media elements, and user experience. This reflects that the trainer kit meets the academic and technical requirements necessary to support practical learning in vocational and engineering education environments. Moreover, student responses during the trial phase demonstrate that the trainer kit is easy to understand and operate. The clarity of the instructional layout, the logical arrangement of control components, and the structured jobsheet guidance contribute significantly to the usability of the product. Users were able to follow instructions without major difficulties, indicating that the trainer kit not only functions effectively from a technical standpoint but also facilitates an accessible learning experience. These findings support the conclusion that integrating simulation and hands-on activities through a dedicated trainer kit can enhance the learning outcomes in PLC courses. The product bridges the gap between theoretical concepts and practical implementation, helping students grasp abstract control logic principles through direct experimentation. The high feasibility score and positive user feedback affirm the effectiveness of the developed trainer kit in improving student engagement and practical competency.

Conclusion

Based on the results of the research and discussion on the development of a learning media in the form of a *Trainer Kit for Programmable Logic Controller* (PLC), it can be concluded that this product was created as a practical support tool for laboratory activities. The trainer kit was developed using the ADDIE instructional design model, which consists of five main stages: analysis, design, development, implementation, and evaluation. The practical jobsheets for the PLC Trainer Kit were designed based on an analysis of the semester learning plan, resulting in 16 jobsheets and 5 project assignments. These materials collectively address four Course Learning Outcomes (CLOs) and twelve sub-CLOs of the "Programmable Logic Control" course. The evaluation of the PLC Trainer Kit, developed for use in the Electrical Engineering Education Study Program at Universitas Negeri Jakarta, revealed a feasibility score of 97.30% for content, 87.30% for media elements, and 94% based on student trial use. Therefore, it can be concluded that the PLC Trainer Kit is highly feasible and suitable for use as a practical learning tool in the "Programmable Logic Control" course within the Electrical Engineering Education Study Program.

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