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Development of a competency-based plc learning module for TVET education in Malaysian Polytechnics

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Abstract

The increasing significance of Programmable Logic Controllers (PLCs) in modern automation highlights the need for a structured and standardized learning module in Malaysia's polytechnics. Despite the growing demand for PLC expertise, there is no dedicated module that integrates both theoretical concepts and hands-on practical applications in the Programmable Logic Controller & Automation course in the Malaysia Polytechnic program. This conceptual paper proposes the development of a PLC module tailored to the course syllabus, designed to enhance student understanding, engagement, and technical competency. The module will incorporate structured theoretical content, guided practical worksheets, and interactive learning strategies to support both instructor-led and independent learning. To ensure that the PLC learning module materials were developed with high reliability and quality, systematic planning using the ADDIE model is used for the design and development process. Emphasis is placed on enhancing students' understanding of PLC programming and fostering self-learning, as well as serving as a reliable teaching aid for polytechnic lecturers. Currently, the module is still in the design phase of the ADDIE model where the module is being developed based on the result of the preliminary study. This study is expected to contribute to the advancement of PLC education by addressing the gap in structured learning materials and supporting Malaysia's technical and vocational education sector in preparing industry-ready graduates.

Keywords: *Programmable Logic Controllers (PLC), learning module, interactive learning, teaching aid, ADDIE model*

INTRODUCTION

The industry sectors recognize and emphasize training relevant to current industry requirements, ensuring the curriculum is aligned with the demands of the labor market, and producing many graduates with diverse technical abilities and knowledge (Jamil, Sepikun, & Muhammad, 2021). Currently, there are 36 polytechnics in Malaysia, offering various TVET program, including engineering, automotive technology, electrical and electronics, information technology, business, and agriculture (Jabatan Pendidikan Politeknik dan Kolej Komuniti [JPPKK], 2018).

Programmable Logic Control (PLC) and Automation course is a compulsory subject taught during the fourth semester of the Diploma in Electrical Engineering (DET), Diploma in Electrical and Electronic Engineering (DEE) and Diploma in Electronic Engineering (Control) (DJK). Furthermore, it is also one of the elective courses offered for other programmers in the Department of Electrical Engineering at Polytechnic Malaysia. It is conducted for 14 weeks per semester, comprising 2 hours of theory and practical work per week. The theory covers six chapters, namely Introduction to Automation Systems, Logical Sensors and Actuators, Introduction to PLC Systems, PLC Programming, PLC Applications, Installing, Maintenance, and Troubleshooting of PLC Systems (Jabatan Pendidikan Politeknik dan Kolej Komuniti [JPPKK], 2019a).

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PLCs are versatile devices widely used in industries such as automotive, food, textile, packaging, semiconductor, and manufacturing (Patodiya & Singh, 2018; Noor & Nasir, 2020). With the accelerated development of modern automation technology, PLCs play an increasingly significant role in the field of automation, and the demand for PLC technical personnel in various industries is growing (Wang, Liu, Wang, Wang & Yang, 2020; Rusimamto et al., 2021). PLC programming proficiency is a skill that every electrical engineering student must possess, particularly when exploring the field of automation in the future (Pratama, Azman, Zakaria & Khairudin, 2021).

There is much research and study conducted by educators and researchers on how to improve the students' performance and the teaching aids for the PLC course. Most of the studies conducted for the PLC course focused on the development of trainer kits. The trainer kit is used in the laboratory for practical work and as a teaching aid during lecture sessions. Among the researchers who have conducted this kind of study are Chávez and Díaz (2019); Khairuddin, Aziz, Azlan, Karim, and Zian (2019); Silaban and Rizal (2020); Wang et al. (2020); Bouhamadi, Adekanle, Aboulfatah, and El (2021); and Pratama et al. (2021). There are only a few previous studies on the PLC course that cover the development of theoretical modules. Among the researchers who have conducted this kind of study are Habibi and Fieschko (2020), Rusimamto et al. (2021) and Kurniawan, Soeryanto, Adiwibowo, and Arsana (2022).

According to the literature review, currently there is no dedicated module that covers both theory and practical work for PLC and Automation courses in polytechnics in Malaysia. Corresponding to the initial survey done through a Google form with eleven lecturers from ten Malaysia Polytechnics, the lecturers use PowerPoint slides during their lecture sessions, supplemented with books and e-books as reference materials for students. The students will receive practical sheets in one or two ways: either as a complete booklet for the entire semester or individually for each practical work session or activity. Since each polytechnic's lecturers create their own slides, they may vary. However, the core content and taxonomy levels remain the same. This is because of their creation using the Department of Polytechnic and Community College Education (DPCCE) provided uniform syllabus.

To address the limitations of existing teaching methods for the Programmable Logic Control (PLC) and Automation course at Malaysia Polytechnics, a teaching module will be developed to aid the lecturer during the teaching and learning sessions. Therefore, the objective of this study is to design and develop the Programmable Logic Controller module based on the Polytechnic's Programmable Logic Controller & Automation course and to evaluate its effectiveness. The module will consist of theoretical elements of PLC programming using ladder diagrams, examples of ladder diagram simulations, exercises on ladder diagrams and PLC design applications, as well as practical worksheets.

Research Objectives

Even though the DPCCE sets a common syllabus, the teaching materials used in the PLC and Automation course at Malaysian polytechnics differ from one lecturer to the next. The need analysis shows that students generally understand the basic ideas behind PLCs, but they still have trouble with more advanced topics, particularly PLC industrial applications. This indicates a lack in structured learning materials that cohesively combine academic knowledge with practical and industry-oriented applications.

The aims of the study are:

1. To identify the instructional needs in the PLC and Automation course in Malaysian polytechnics.
2. To design and develop a structured PLC learning module based on the ADDIE instructional design model.
3. Propose an evaluation framework to assess the effectiveness of the developed module in future implementation phases.

LITERATURE REVIEW

A programmable logic controller (PLC) is an industrial-grade, programmable electronic device that controls industrial processes by executing user-programmed instructions (Bouhamadi et al., 2021). PLCs use programmable memory to store instructions and perform specific functions, including logic operations, timing, counting, and arithmetic operations (Bolton, 2015). PLCs are versatile devices widely used in industries such as automotive, food, textile, packaging, semiconductor, and manufacturing (Noor and Nasir, 2020). With the accelerated development of modern automation technology, PLCs play an increasingly significant role in the field of automation, and the demand for PLC technical personnel in various industries is growing (Rusimamto et al., 2021).

Previous studies highlight the necessity of conducting preliminary research before module construction to guarantee that the instructional product meets learners' needs and contextual learning problems. Difinubun, Makmuri and Hidayat (2024) emphasized that requirements analysis via observations, interviews, questionnaires, and diagnostic tests yields empirical evidence of students' learning challenges and deficiencies in current teaching resources prior to the development of a project-based learning module. Anista et al. (2022) similarly showed that initial research, such as teacher interviews and classroom observations, is necessary to find flaws in current textbooks and teaching methods before designing a problem-based learning module. These results indicate that a need-driven development methodology improves the module's relevance, feasibility, and instructional coherence. A comprehensive preliminary study guarantees that the produced module is not solely theoretical but is rooted in genuine educational challenges, learner attributes, and curriculum demands, hence enhancing its potential efficacy and practical application.

The PLC module is developed using the ADDIE model, applying behaviorism and cognitivism learning theories. The ADDIE model is a commonly used instructional design framework in education. Dick and Carey (1996) state that ADDIE stands for Analysis, Design, Development, Implementation, and Evaluation. Hamid et al. (2020) emphasize that the model's structured activities, developed according to students' requirements and characteristics, ensure that the final learning product is constructed correctly and aligned with the desired outcomes.

In the analysis phase, the students' requirements, learning objectives and the learning environment were identified and analyzed (Jalil, Madar, & Kassim, 2020). During the design phase, a complete instructional plan must be created that shows the content organization, instructional strategies, and assessment methods Based on the design phase results, the learning material will be developed, incorporating elements such as user guides, instructional content, training, and stimulating materials (Boyman et al., 2020). The implementation phase involves using the developed teaching modules in the classroom to evaluate the modules' efficacy and feasibility (Samsudin et al., 2021). The evaluation phase is an ongoing process throughout the ADDIE model, evaluating the effectiveness of the developed instructional materials, students' performance, and overall learning experiences (Ramadhan & Murtinugraha, 2020).

The ADDIE model has been used in various developments of educational contexts, including creating software, applications, instructional modules and teaching aids. Among the researchers that have used the ADDIE model for this purpose are Boyman, Jamal, Razali, and Abdul Aziz (2020); Ramadhan and Murtinugraha (2020); and Kurniawan et al. (2022).

There are two variables in this research, namely the independent and dependent variables. The dependent variable is an attribute or characteristic influenced or affected by the independent variable (Creswell, 2009). For this study, the PLC module is the independent variable, while the effect on the student learning outcome is the dependent variable.

METHODOLOGY

The research design of this study is module development, where the ADDIE model will be applied during the design, development and implementation process. This study used a quantitative approach because the instruments provided data in numbers, which were analyzed using statistical tests (Creswell, 2009). This design has been selected in this study because one of the objectives is to evaluate the effect of using the Programmable Logic Controller module among the electrical engineering students at the Malaysia Polytechnic. Figure 1 shows the research design to develop the PLC module using the ADDIE model for instructional design. The process is adapted from Kulvietiene & Sileikiene (2006).

This study is an experimental study in which one or more variables are altered in the experimental group (Dewi & Primayana, 2019). This study utilised a quasi-experimental approach, which is a one-group pre-test and post-test design to assess the effectiveness of the developed module (Kim, Gu, & Chang, 2019; Devkota, Dahlke, Fox, Davidson, Hunter, Butler, Shrestha, Chasteen, Moody, Martin, & Pietrosanu, 2023). The experimental group underwent the module intervention, while the control group followed the regular curriculum without manipulation. As a result of this approach, it was possible to assess the change in performance of students in the experimental group; thus, the efficacy of the PLC module will be determined.

Quasi-experimental research is commonly employed to study causal links between variables, especially when random assignment is not possible (Baker, 2017). In this study, the PLC module is the independent variable, while student learning results are the dependent variable. In contrast with true experimental designs, which randomly assign respondents to groups, this study uses an existing intact class to avoid disturbing scheduled ongoing classes (Alwi, 2019).

For the implementation phase, two groups of samples are used: 30 students for module reliability during the pilot test and six content experts for the module validity. All the participants and the content experts will be briefed on the purpose of the pilot test, survey, and module validation. The students could withdraw at any time during the testing period. Furthermore, the participants' confidentiality and privacy are also strictly maintained (BERA, 2024).

For the pilot testing, the participants were 30 students enrolled in the Diploma in Electrical Engineering (Semester 4) at Politeknik Sultan Azlan Shah. These students were selected through purposive sampling based on their registration in the PLC & Automation course. They are in the target population but not the final sample. The students will be given the pre-test, post-test and the intervention, the PLC module. The pre-test and post-test will be conducted simultaneously, before and after the completion of the quasi-experimental. Lastly, the students will be given a survey to get the students' feedback regarding the usability, clarity, content quality, and overall learning experience provided by the module. The module reliability is determined by calculating Cronbach's alpha coefficient for each survey item in the survey. A Cronbach’s alpha value between 0.8 and 0.9 is classified as very satisfactory, while values between 0.7 and 0.8 are considered good (Hair, 2010).

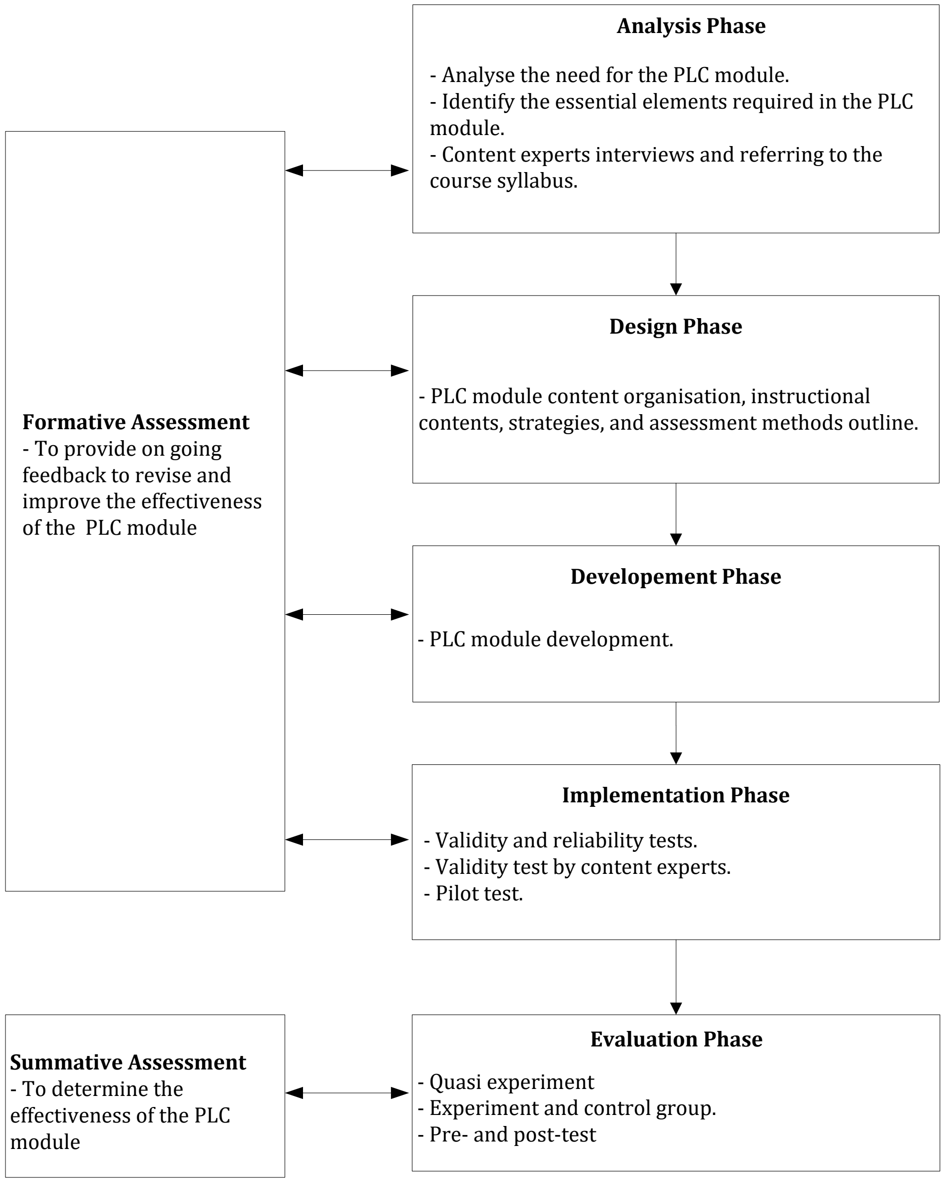

Figure 1. PLC Module Research Design Process

In addition, for module content validation, seven experts in the PLC field from various institutions and industries will review the module content. All the feedback from the students and experts will be used to improve the module content. The experts chosen to have more than ten years of working experience with the PLC, either in an educational or in an industrial context. To determine the validity of the module content, the expert's total score (x) will be divided by the maximum score (y) and multiplied by one hundred. The formula is as stated below:

$$\frac{\text{Total Expert Score (x)}}{\text{Maximum score (y)}} \times 100\% = \text{Level of Module Validity Percentage}$$

The module validity questionnaire is an adapted version of Sidek and Jamaludin's (2005) questionnaire designed to assess the content validity of a module. They used Russell's (1974) content validity criteria, which include five important points: (a) the module content is appropriate for the target population, (b) the teaching methods or module implementation strategies is appropriate, (c) the time given for module implementation is sufficient, (d) the module should effectively improve student achievement in the targeted area, and (e) the module should successfully change student attitudes. This questionnaire is in the form of a five-point Likert scale, namely Strongly Agree (5), Agree (4), Uncertain (3), Disagree (2), and Strongly Disagree (1).

During the evaluation phase where the quasi-experiment will be conducted, students from two different polytechnics will be selected using purposive sampling. Two intact classes from each polytechnic will be selected, where one class is the control and one class is the experimental group. Both groups will be given the pre-test and post-test, but only the experimental group will be given the intervention, the PLC module.

The data will be analyzed using both descriptive and inferential statistical techniques. The descriptive analysis will be used to analyze the results from the questionnaire on the validity of the module's content and students' acceptance and perception of the module. The SPSS software will be used in this analysis, and the data presented demonstrates the mean, frequency, standard deviation, and percentage. The results from the pre- and post-tests will be analyzed using inferential analysis. Based on the percentage of students' scores on both tests, the obtained data was analyzed to determine the difference between the outcomes of the control and experimental groups. The t-test was used to analyze the significant difference between the outcomes of both groups.

RESULTS AND DISCUSSION

Needs Analysis (ADDIE – Analysis Phase)

A needs analysis was conducted to assess students' understanding and lecturers' evaluation of students' competency across six chapters of the PLC & Automation course. 150 students from four polytechnics and eleven lecturers from ten polytechnics responded to the study via Google Forms. The topics were determined using the mean value as shown in Table 1. This analysis represents the ADDIE instructional design model's analysis phase, where learning gaps, essential skills, and instructional needs are carefully identified before module construction.

Table 1. Mean Score by Chapter

Chapter	Topic	Mean (Lecturers)	Mean (Students)
1	Introduction to Automation System	3.42	4.02
2	Logical Sensors & Actuators	3.24	3.99
3	Introduction to PLC System	3.79	4.10
4	PLC Programming	3.51	3.97
5	PLC Applications	2.73	3.87
6	Installation, Maintenance & Troubleshooting	3.32	3.84

Design Requirements (Transition from Analysis to Design Phase)

Based on the finding in the analysis phase, the PLC module content is developed. Table 2 shows the instructional design strategy derived from the analysis phase. The identified instructional gaps that the module will be focusing on are Chapter 5 and Sequential Instruction Function in Chapter 4. To ensure that the module development is aligned with the identified requirements in the analysis phase, each identified learning gap is translated into a specific design principle, instructional intervention, and measurable performance indicator.

Table 2. Instructional Design Strategy Derived from the Analysis Phase

Identified Learning Gap (Analysis Output)	Design Principle	Instructional Intervention (Module Component)	Performance Indicator / Assessment Evidence
Difficulty applying special sequential PLC instructions	Progressive cognitive scaffolding	Structured ladder development tasks (basic → intermediate → integrated system)	Sequential instruction mastery assessment (program correctness & logic flow)
Gap between programming syntax and integrated system design	Integrated system-based design approach	Mini-capstone ladder integration project combining programming, wiring, and safety logic	Rubric-based evaluation (logic accuracy, system completeness, safety compliance)
Weak industrial PLC application design competency	Authentic, competency-based learning	Industrial case-based scenarios with complete I/O mapping and system constraints	Capstone industrial automation mini-project evaluated using industry-aligned rubric

The structured mapping in Table 2 illustrates the methodological consistency of the ADDIE model, as the findings from the Analysis phase directly affect the Design phase. The developed PLC module prioritises measurable skill growth over content coverage solely due to the alignment between performance-based assessment strategies and identified learning gaps.

The developed module content will go through continuous improvement based on the feedback from the students' perception survey during the pilot test and from the expert review from academic and industry professionals. This will ensure that the developed module is aligned with industrial practices and educational standards.

This study is expected to contribute significantly to the field of technical and vocational education and training (TVET), especially in instructional module development for automation courses. In addition, this study may benefit students by providing a more engaging and comprehensive learning experience, combining both theoretical understanding and practical skills in one complete module.

CONCLUSIONS

In response to the growing demand for skilled automation professionals in the era of Industry 4.0, this study proposes the development of the PLC module based on the polytechnic syllabus. This study examined the instructional needs of the PLC & Automation course in Malaysian polytechnics and translated the identified learning gaps into structured instructional design strategies guided by the ADDIE model.

The result in the analysis stage showed that there was a learning gap in students' performance, where students demonstrated relatively strong understanding of fundamental PLC concepts but encountered difficulties in industrial application design and advanced ladder logic construction. Hence, these findings validated the need for a structured PLC learning module focusing on scaffolded ladder programming, case-based industrial tasks, and hardware–software integration exercises.

By incorporating both theory and practical components using structured instructional design of the ADDIE model and reliable pedagogical principles, the module aims to improve students' mastery of PLC systems. Additionally, if the expected outcomes are achieved, this study may provide strong justification for incorporating the developed module into the official teaching resources for PLC and Automation courses in Malaysian polytechnics.

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