Using Problem-Based Learning Activities to Enhance Systematic Thinking in Electrical Power Engineering Students

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Abstract
This research was prepared for Promote the ability to think systematically about drawing ladder diagrams in the Mable Logic Control program. The sample consisted of 18 3rd year vocational certificate students. The data collection method was simple random sampling using lots. The experimental research design used in the experiment was a study of a single experimental group. Measured only after the experiment. The single group, posttest-design.The tools used in the research include: Problem-based learning management activities Measurement of systematic thinking ability (after class). Steps for creating it: 1. Study teaching and learning problems in the classroom. 2. Study principles concepts and theories. 3. Determine the structure and steps. Teaching and learning innovation. 4. Create innovation. 5. Create measurement tools. Ready to find the quality of the tools. 6. Take the innovation to be evaluated by experts to check the quality. 7. Take the modified innovation and use it to teach with real sample groups. The results of the research found that it has a mean value of ($\bar{x}$=4.69, SD=0.48) considered consistent with the assumption that it is at the passing level. (Learners passed the criteria of 80 percent or more of all students). The results of the 1st and 2nd systematic thinking ability tests were overall at a better level (with a score of 7 and above). The number of 16 people is 88.88 percent and the number of 15 people is 83.33 percent, which is according to the assumptions made.

Keywords: Problem-Based Learning, Systematic Thinking, Programmable Logic Control

Introduction

In an era marked by rapid changes in technology and innovation, systematic thinking skills have become essential for solving complex problems and decision-making processes across various disciplines, particularly in the field of electrical engineering, which necessitates analysis and design. Systems thinking helps students understand and analyze problems structurally, see relationships between system elements, and perform precise and systematic operations. This is because electrical engineering work involves the integration of knowledge from many fields and requires a thinking process that can consider all relevant factors thoroughly and carefully. However, the past evaluation of students' learning outcomes in the electrical engineering program revealed, based on past score statistics, that the programmable logic control course used pre-test and post-test to measure learning achievement. The test revealed an increase in the students' post-test scores. but when the students went out to practice their professional experience, they often had problems applying theoretical knowledge to real situations. They lacked the ability to connect problems and analyze them from various perspectives. These skills are important for the development and maintenance of complex electrical systems. There is a learning management method that emphasizes solving real problems through practice or problem-based learning. Over the past few decades, numerous new learning theories have emerged. However, the most popular learning theory among educators is the constructivist learning theory, which incorporates a concept that aligns with 21st-century education: the learning management model using PBL. The Faculty of Health Sciences at McMaster University initially developed it. Later, this method became a learning model. Teaching using the PBL model has begun to expand to other fields, such as engineering, science, and mathematics. Therefore, such a teaching model is an appropriate approach to developing students' systems thinking skills,as PBL emphasizes students' participation in the learning process through solving problems that are close to real situations. This allows students to practice problem analysis, information search, and knowledge integration to find answers, resulting in deeper and more sustainable learning. This research aims to study the use of PBL activities in the Programmable Logic Control: PLC course to enhance systems thinking skills in electrical engineering students. This course is crucial in training and developing basic knowledge about programming to control the operation of automatic systems, which is one of the essential skills for electrical engineers in the present era.

Based on the aforementioned problems, this research aims to enhance systems thinking skills in electrical engineering students by studying and applying PBL learning activities in the PLC subject, specifically in the sub-units of Writing Ladder Diagrams for Programmable Logic Control (LAB4: Traffic Signal Control, LAB5: Workpiece Distribution Station Control). The focus is on the learning process during the study rather than the traditional pre - and post-test assessment. Therefore, this research measured the development of students' skills during the study by administering two tests, a departure from the traditional assessment method that typically uses a pre-test and a post-test. This research employs a process-based assessment method to monitor the advancement of students' systems thinking throughout the study.

This research aimed to enhance the ability of systematic thinking in terms of analytical thinking and applied thinking by PBL activities in a lesson on writing ladder diagrams for PLC. The PBL learning management effectively and significantly developed analytical and applied skills for electrical engineering students. Furthermore, students can apply the concepts they gained from such activities to their future work.

Overview of the Research

Concepts and Theories of Problem-Based Learning (PBL) Management to Develop Systematic Thinking

Learning using PBL is a process that starts with presenting a problem situation for learners to connect their previous knowledge with new information, leading to knowledge creation and the development of analytical thinking skills. This type of learning emphasizes that learners practice solving problems systematically, searching for information by themselves, and enhancing their academic understanding through real situations instead of teaching by lecturing. In PBL, the teacher will be the facilitator and prepare questions that are consistent with the learning objectives, encouraging learners in small groups to participate in analyzing problems, forming hypotheses, testing, and summarizing new knowledge without providing direct information. There are three main aspects 1. activation of prior knowledge, 2. encoding specificity and 3. elaboration of knowledge. In this regard, teaching should focus on activities that allow learners to express and extend their knowledge.

The learning process using PBL, as illustrated in Figure 1 (Boom et al., 2010) consists of six main steps.

1. **Problem Identification:** The teacher divides students into groups to jointly identify problems and clearly define the scope of the problem according to the assigned task.
2. **Brainstorming:** Students in each group brainstorm, analyze, and break down problems by linking them to their prior knowledge to understand them from various perspectives.
3. **Problem Analysis:** The students analyze problems using reasoning, set learning objectives, and identify additional information necessary to explain them.
4. **Planning:** The students plan their research by dividing tasks and identifying the sources of information they need to use to collect new knowledge and related information.
5. **Learning and Application:** The students apply the new information and knowledge they have gained from their research to solve problems, using related concepts, principles, and theories to find possible answers.
6. **Summary and Report:** The students summarise their knowledge and present the results of problem solving by linking the concepts studied and showing the results obtained from applying the knowledge.

We will use the aforementioned PBL steps to assess learning outcomes, assisting learners in systematically developing critical thinking and problem-solving skills.

Figure 1: Learning Process Using PBL

The Concepts and Related Theories of System Thinking Encompass Both Analytical and Applied Thinking

System thinking refers to the ability to apply knowledge and analysis to solve problems in real situations effectively. This type of thinking allows learners to connect theoretical knowledge with real situations, which deepens applied thinking. In order to develop a problem-solving method that is consistent and appropriate for real situations, applied thinking takes into account both theoretical factors and the context of the problem at hand. For instance, when solving the problem of drawing a ladder diagram in an automatic control system, learners need to apply their knowledge of electrical circuit design and PLC operation to the functioning of a real, complex industrial system. Applied thinking helps learners to evaluate possible outcomes and decide on the most appropriate solution. This research uses system thinking, analytical thinking, and application thinking.

Analytical Thinking.

Analytical thinking, in the context of systems thinking, emphasizes the separation of elements within a system and the identification of relationships among them. This method of thinking enables learners to explore the intricacies of each element and uncover hidden patterns within the system. Analytical thinking also helps learners to consider the structure of the system and the factors that affect its operation systematically. For example, in analysing an electrical system, learners may start by breaking down the elements, such as voltage, current, and conductors, and then study how these elements work together in the system. Analytical thinking also helps learners to identify the causes of problems and the factors that affect their occurrence more clearly, which is an important foundation for effective problem solving.

Applied Thinking.

In the context of systems thinking, applied thinking refers to the capacity to effectively apply knowledge and analysis to solve problems in real-world situations. This type of thinking helps learners to connect theoretical knowledge with real situations, which deepens applied thinking. In order to develop a problem - solving method that is consistent and appropriate for the real situation, applied thinking takes into account both theoretical factors and the context of the problem at hand. For instance, in order to solve the problem of drawing a ladder diagram in an automatic control system, learners must apply their knowledge of electrical circuit design and PLC operation to the functioning of a real, complex industrial system. Applied thinking helps learners to evaluate possible outcomes and decide on the most appropriate solution.

Systems thinking, which combines analytical and applied thinking skills, enables learners to deal with complex problems, see holistic relationships, and carefully evaluate the impact of individual changes in a system. It prepares learners to effectively deal with challenging problems and adapt in an ever-changing environment.

The Process of Learning Management Design Involves Creating Ladder Diagrams With Programmable Logic Control Through PBL, Which Fosters System Thinking

The design of learning management, which is used in teaching the topic of writing programmable logic ladder diagrams using PBL to develop systematic thinking (analytical thinking and applied thinking), follows six steps:

- **Step 1: Problem Identification:** Learners will receive problems related to writing ladder diagrams with PLC for automatic system control, such as "Design a ladder diagram to control an electric motor to work according to specified conditions." The teacher will help explain the importance of writing ladder diagrams with PLC and ask questions to stimulate learners to think further.
- **Step 2: Brainstorming:** Divide into groups and discuss the given problem to understand its details, including the motor's function and various working conditions. Learners can use diagrams or notes to help analyze the problems they receive and the relationship between different devices.
- **Step 3: Problem Analysis:** In this step, learners are required to explore online resources for information on writing ladder diagrams, with the aim of comprehending the working principles of PLC and the structure of ladder diagrams. Learners should focus on studying the differences between devices and different control methods.
- **Step 4: Planning:** After studying and researching, learners must synthesise the obtained data to create a basic ladder diagram. Planning the diagram may involve creating a mind map or diagram flow to clearly illustrate the control steps. It is necessary to consider the relationship and priority of the devices used.
- **Step 5: Learning and application:** In this step, learners are required to summarize and assess the ladder diagram design they have created, either through a written report or a group presentation. Having friends assist in evaluating the correctness and reasonableness of the design fosters participatory learning.
- **Step 6: Summary and Report:** In the final step, each group of learners must present their ladder diagram writing results in front of the class. The teacher may either demonstrate the actual work or use software to simulate the operation of the PLC. The teacher will evaluate both the content and the presentation, including providing suggestions to learners for development next time.We conducted a test twice after organizing the learning of all 6 steps, utilizing problem-based learning to develop a systematic approach to creative and applied thinking, particularly in the area of writing ladder diagrams for programmable logic control.

Analysis of Data Results

The Quality Assessment of Learning Management Plans Yielded Results

Ability to foster systematic thinking through the use of PBL in organizing learning activities related to writing ladder diagrams with PLC as evaluated by three experts. We conducted the quality assessment using the activity quality assessment form, a questionnaire featuring a rating scale for five areas: 1. overall structure of the plan 2. learning objectives 3. learning activities 4. learning media and 5. measurement and evaluation. We analyzed the evaluation values obtained using Likert rating scales (Wratten et al., 2022). The analyzed values consisted of the mean and the standard deviation (SD). We determined the range of the mean values to interpret the meaning into 5 levels (Likert, 1932): (4.50-5.00=Very Satisfied), (3.50-4.49=Satisfied), (2.50-3.49=Neutral), (1.50-2.49=Dissatisfied), and (1.00-1.49=Very Dissatisfied), as shown in Tables 1 to 5.

Table 1: Results of the Study of the Quality of Learning Management Activities in the Overall Plan

Evaluation List	Mean	SD	Opinion Level
1.1 The plan covers all necessary elements.	5	0	Very Satisfied
1.2 The learning management plan is feasible for implementation.	4.67	0.58	Very Satisfied
1.3 The plan is designed to address the needs or solve the problems of learners by enhancing their thinking or higher-level abilities.	4.67	0.58	Very Satisfied
1.4 The plan is easy to understand, allowing others to teach it effectively.	4.67	0.58	Very Satisfied
1.5 Summarize the main ideas in a way that is consistent with the content to be taught.	4.67	0.58	Very Satisfied
Overview of Section 1	4.74	0.48	Very Satisfied

Overall Plan: The overall plan is at a Very Satisfied level: All 5 items are: 1.1 Behavioural objectives, content, teaching methods, materials or media, measurement and evaluation, and post -teaching records are all included. You can put the learning management plan into practice. 1.3 The plan aims to meet the needs of the learners or solve their problems in terms of high-level thinking or abilities. 1.4 The plan is simple to comprehend, allowing others to instruct in its place. Provide a concise overview of concepts that align with the intended teaching content. The average score is ($\bar{x}$=4.74, SD=0.48) for all 5 items, which indicates that the overall quality of the plan is appropriate and of high quality.

Table 2: Results of the Study of the Quality of Learning Management Activities in the Learning Objectives

Evaluation List	Mean	SD	Opinion Level
2.1 The learning objectives adequately cover the content/subject matter.	5.00	0	Very Satisfied
2.2 Learning objectives are derived from indicators.	4.33	0.58	Very Satisfied
2.3 Write behavioral objectives that are clear, measurable, and observable.	4.67	0.58	Very Satisfied
2.4 Learning objectives aim to develop learners' knowledge, skills, and processes that are important in the current era.	4.67	0.58	Very Satisfied
Overview of Section 2	4.67	0.44	Very Satisfied

In terms of learning objectives, the overall quality is at the Very Satisfied level: Three learning objectives are rated as very good, with the highest mean value being as follows: 2.1 Learning objectives cover the subject matter/content with the mean value of ($\bar{x}$=5.00, SD=0). 2.2 Learning objectives are derived from indicators with the mean value of ($\bar{x}$=4.33, SD=0.58). 2.3 Clearly write behavioural objectives that can be measured or actually observed with the mean value of ($\bar{x}$=4.67, SD=0.58).2.4 Learning objectives aim to develop learners in terms of knowledge and skills of processes that are important in the current era with the mean value of ($\bar{x}$=4.67, SD=0.58), which indicates that the learning objectives are appropriate and achieve the objectives.

Table 3: Results of the Study of the Quality of Learning Management Activities in the Learning Activities

Evaluation List	Mean	SD	Opinion Level
3.1 Learning activities are consistent with the objectives.	5	0	Very Satisfied
3.2 Learning activities are consistent with the content.	5	0	Very Satisfied
3.3 Activities are designed to train learners on indicators during the study and relate to the measurement of all indicators after the study.	5	0	Very Satisfied
3.4 Techniques for organizing learning activities are aligned with the behavioral objectives.	4.67	0.58	Very Satisfied
3.5 The plan includes all main steps of the process, clearly defining the introduction, teaching, and conclusion phases.	4.67	0.58	Very Satisfied
Overview of Section 3	4.89	0.23	Very Satisfied

Overall, the learning activities were Very Satisfied level: There was especially good learning in all 5 items: 3.1 learning activities of the program; 3.2 learning activities in the content area; 3.3 training activities for learners to be able to learn related to all outcomes after learning with the same intensity ($\bar{x}$=5.00, SD=0); 3.4 a technique for inheriting learning with a strategic approach; and 3.5 the main steps are detailed according to the original subject, making it clear that the leading step, the teaching step, and the conclusion step are all carried out equally ($\bar{x}$=4.67, SD=0.58). The activities involve learning.

Table 4: Results of the Study of the Quality of Learning Management Activities in the Learning Media

Evaluation List	Mean	SD	Opinion Level
4.1 Media and learning resources are easy to understand and help learners achieve their objectives more effectively.	4.33	0.58	Very Satisfied
4.2 The media used is consistent with the content.	4.67	0.58	Very Satisfied
4.3 The media is engaging and user-friendly.	4.67	0.58	Very Satisfied
Overview of Section 4	4.56	0.58	Very Satisfied

The overall quality of learning media is Very Satisfied level: item 4.2, where the media used is consistent with the content, meets the learning objectives at a very high level. 4.3, the media is interesting and easy to use, with an average value of ($\bar{x}$=4.67, SD=0.58), and item 4.1, the media and learning resources are easy to understand and help learners achieve their objectives more easily, at a good level, with an average value of ($\bar{x}$=4.33, SD=0.58), which indicates that the learning media is of good quality and appropriate for learners.

Table 5: Results of the Study of the Quality of Learning Management Activities in the Measurement and Evaluation

Evaluation List	Mean	S.D.	Opinion Level
5.1 Methods of measurement and evaluation are aligned with the behavioral objectives.	4.67	0.58	Very Satisfied
5.2 The questions for measurement and evaluation are clear.	4.67	0.58	Very Satisfied
5.3 The measurement tools and methods are appropriate for the learners' ability levels.	4.67	0.58	Very Satisfied
5.4 Multiple measurement opportunities are provided to allow learners to improve.	4.67	0.58	Very Satisfied
Overview of Section 5	4.67	0.58	Very Satisfied

In terms of measurement and evaluation, it is at a Very Satisfied level overall, with learning objectives that are at a very good level in all 5 items, namely: 5.1 The methods of measurement and evaluation align with the behavioural objectives. 5.2 The questions for measurement and evaluation are clear. 5.3 The measurement tools and measurement methods are appropriate for the learner's ability level. 5.4 There are multiple measurements that allow the learner to improve. The average values of all 5 areas are equal, with ($\bar{x}$=4.67 and SD=0.58) indicating that the measurement and evaluation aspects are appropriate.

The Results of the Measurement of the Ability to Think Systematically on the Topic of Drawing Ladder Diagrams With PLC

Results of the systematic thinking ability measurement on the writing of ladder diagrams with PLC for 18 electrical engineering students were evaluated using the 5-point rating scale Rubric score. (Wind, 2020) The criteria of the 5-level rating scale for the evaluation of the results include (5=excellent), (4=good), (3=average), (2=poor), and (1=very poor). We will evaluate it after learning through individually designed activities, based on the indicators of systematic thinking ability, analytical thinking ability, applied thinking ability, and overall thinking ability. We divide the results of the systematic thinking ability measurement into two categories: the first post-learning ability measurement (E1) and the second post-learning ability measurement (E2), both of which must pass the 80 percent criterion or receive a score of 4 or higher. The results are shown in Tables 6 and 7.

Table 6: Results of the First Systematic Thinking Ability Measurement

Opinion for Quality		Quantity	Percentage	Opinion for Quality		Quantity	Percentage
1.Analytical thinking ability (5 points)				**3.Applied thinking ability (5 points)**			
Pass	Excellent	18	100	Pass	Excellent	-	88.88
	Good	-			Good	16	
Failed	Average	-	-	Failed	Average	2	11.12
	Poor	-			Poor	-	
	Very Poor	-			Very Poor	-	
2.Ability to think systematically (5 points)				**Total score (15 points)**			
Pass	Excellent	4	77.78	Pass		16	88.88
	Good	9					
Failed	Average	5	22.22	Failed		2	11.12
	Poor	-					
	Very Poor	-					

From Table 6, the first systematic thinking ability measurement yielded results from the initial ability test. From the test results in the first indicator of the analytical thinking ability assessment, analytical thinking ability, there were 18 students in total, all of whom scored at the excellent level, accounting for 100 percent. The percentage of those who passed the criteria in the second indicator, ability to think systematically, had 4 students with excellent scores, 9 students with good scores, and 5 students with average scores. The number of those who passed the criteria was 77.78 percent, and the number of those who did not pass the criteria was 22.22 percent. In the third indicator, applied thinking ability, there were 16 students with good scores, 2 students with average scores, and those who did not pass the criteria were 88.88 percent and those who did not pass the criteria were 11.12 percent. When the scores of all 3 indicators in the first ability test were combined, it was found that 88.88 percent passed the criteria and 11.12 percent did not pass the criteria, as shown in Figure 2. The percentage of those who passed the criteria was consistent with both the hypothesis and the criteria. Significantly defined.

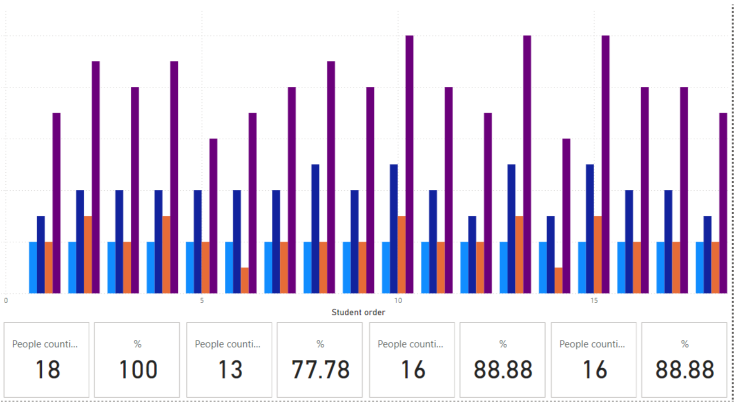

Figure 2: The Results of the First Systematic Thinking Ability Measurement

Table 7: Results of the Second Systematic Thinking Ability Test

Opinion for Quality		**Quantity**	**Percentage**	**Opinion for Quality**		**Quantity**	**Percentage**
1.Analytical thinking ability (5 points)				**3.Applied thinking ability (5 points)**			
Pass	Excellent	17	94.44	Pass	Excellent	8	83.33
	Good	-			Good	7	
Failed	Average	1	-	Failed	Average	3	16.67
	Poor	-			Poor	-	
	Very Poor	-			Very Poor	-	
2.Ability to think systematically (5 points)				**Total score (15 points)**			
Pass	Excellent	6	77.78	Pass		15	83.33
	Good	7					
Failed	Average	5	22.22	Failed		3	16.67
	Poor	-					
	Very Poor	-					

From Table 7, results of the first systematic thinking ability measurement from the first ability measurement test. From the test results in the first indicator of the analytical thinking ability assessment, analytical thinking ability, there were 18 students in total, with 17 students scoring at the excellent level and 1 student at the average level, accounting for 94.44 percent who passed the criteria and 5.56 percent who did not pass the criteria. In the second indicator, ability to think systematically, there were 6 students with excellent scores, 7 students with good scores, and 5 students with average scores. The number of students who passed the criteria was 77.78 percent, and the number of students who did not pass the criteria was 22.22

percent. In the third indicator, applied thinking ability, there were 8 students with excellent scores, 7 students with good scores, and 3 students with average scores. When the scores of all three indicators in the second ability measurement were combined, it was found that 83.33 percent passed the criteria and 16.67 percent did not, as shown in Figure 3. The percentage of those who passed the criteria was significantly consistent with the hypothesis. The number of students who passed the criteria was 83.33 percent and the number of students who did not pass the criteria was 16.67 percent.

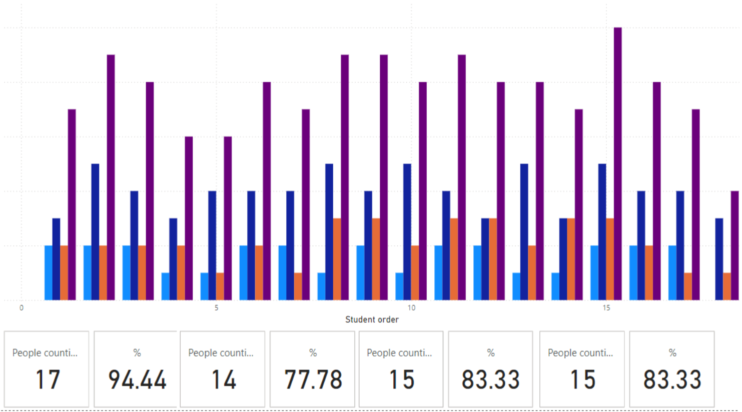

Figure 3: Results of the Second Systematic Thinking Ability Measurement Test

Conclusion

The study focuses on fostering systematic thinking skills in both creative and applied thinking, specifically in the area of ladder diagram creation in PLC, through the implementation of the PBL learning management method for electrical engineering students. The study evaluated the quality of the learning management plan. In the evaluation of the quality of the learning management activities in all five areas, the average evaluation result was ($\bar{x}$=4.69, SD=0.48). This suggests that the quality of the learning management plan is good and appropriate. This is consistent with the hypothesis in terms of learning objectives and learning activities. From the first systematic thinking ability assessment in calculating the total score of all three indicators, it was found that 88.88 percent passed the criteria. From the second systematic thinking ability assessment in calculating the total score of all three indicators, it was found that 83.33 percent passed the criteria, which is in accordance with the hypothesis that In the sample group, there must be those who pass the criteria with a score of at least good level, not less than 80 percent, for both the first systematic thinking ability test and the second systematic thinking ability test. However, the results of both assessments suggest that students can achieve learning objectives in line with the hypothesis and enhance their systematic thinking skills in the PLC subject. These skills will enhance their analytical thinking capabilities and enable them to apply them to real-world tasks in the future.

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