

The effect of Problem-based Learning (PBL) with mockup media in learning programmable logic controller

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ABSTRACT

This research aims to (1) examine the differences in learning outcomes of programmable logic controllers between cadets who use problem-based learning strategies assisted by mockup media and problem-based learning strategies, (2) examine the differences in learning outcomes of programmable logic controllers between cadets who have high and low initial abilities, and (3) examine the interaction effect between learning strategies and initial abilities on learning outcomes of programmable logic controllers. This research uses a 2 x 2 factorial design with the object of research being the 3rd-semester airport electrical engineering study program students at Aviation Polytechnic Surabaya. The sample of this research includes 47 students of the TLB 11 AB class as the experimental group of problem-based learning strategy assisted by mockup media and 46 students of the TLB 12AB class as the control group of problem-based learning strategy. A learning outcomes test collected the data on learning outcomes in the form of multiple choice. Learning outcomes data were analyzed using two-tailed ANOVA (analysis of variance). The results showed that there is a significant difference in learning outcomes of the programmable logic controller between cadets who learn using problem-based learning assisted by mockup media and problem-based learning, there is a significant difference in learning outcomes of the programmable logic controller between cadets who have high and low initial abilities, there is no interaction effect between learning strategies and cadets' initial abilities on learning outcomes of the programmable logic controller. This research can contribute to improving students' understanding and skills in the field of PLC. Through practical experience and relevant projects, students can develop a deeper understanding of PLC concepts and improve their technical skills in designing, implementing, and solving problems related to PLC systems.

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INTRODUCTION

One of the objectives of vocational education is to develop students' expertise. In this case, vocational learning models that can be developed are teaching methods, learning skills, work skills, and technical skills (Chinedu et al., 2015; Yusof et al., 2015). Furthermore, with the development of the vocational model, it is expected that highly skilled educational outputs with global standard expertise, employability skills, and four life skills, namely academic skills, social skills, personal skills, and vocational skills, will be obtained (Mohamed et al., 2021; Vona et al., 2018).

In the process of acquiring academic expertise, learning outcomes can be one measure of success. Student learning outcomes are influenced by many things, such as learning methods applied by teachers, classroom climate, student attitudes, teaching work groups, the amount of teaching work each week, class signatures, student administration, Continuous Assessment Test (CAT) results, personal attention from teachers to students, the time it takes teachers to complete the syllabus, setting certification performance targets, communication and appropriate approaches, learning facilities, mentoring, family pressure, learning styles, previous academic achievements, academic resources, self-efficacy, self-regulation, student abilities, cognitive abilities and personality, learning strategies (Aguilera-Hermida, 2020; Baber, 2020; Nortvig et al., 2018; Van der Kleij et al., 2015).

Related to learning strategies, student-centered learning emphasizes the role of students to be more active in the learning process, whereas one form of student-centered learning that has been widely applied and is able to affect student learning outcomes is problem-based learning. The things that must exist in problem-based learning are (1) engagement, which prepares students to act as problem solvers by working together; (2) inquiry and investigation, which digs up and distributes information; (3) performance, which presents the findings; (4) question and answer which aims to test the accuracy of the solution; and (5) reflection on problem-solving (Ahdhianto et al., 2020; Siagian et al., 2019; S. J. Simamora et al., 2017).

One of the subjects in the aviation vocational education curriculum is Programmable Logic Controller (PLC). PLC courses learn about logic, input-output, memory, timing, and the use of control instructions in ladders or mnemonics in PLC software to make it easier to control tools in industry (Maniriho, 2019; Sadi, 2015). To learn PLC, a learning method is needed that encourages students to find out for themselves factually through problem-solving and not just abstract concepts in PLC software; these problems can be found in real industrial control systems and everyday life.

PLC learning, especially in control circuit planning and analysis, will be more meaningful if students can solve problems, apply their knowledge and abilities, and apply concepts and procedures. PLC learning starts with problems, then students hone their abilities to solve these problems. Students can choose or find interesting problems to solve according to the material topic so that they are motivated to play an active role in learning (Hew, 2016; Hwa, 2018; Pattiwael, 2019).

PLC is a subject that uses a set of instructions or commands arranged in such a way with the right sequence of reasoning to solve a problem (Rusimanto et al., 2019). Meanwhile, Fronchetti et al. (2022) stated that mastering PLC requires ladder logic programming to create simple automation. One of the learning methods that is likely to improve student learning activities and outcomes in PLC control system programming subjects is Problem-based Learning (PBL).

In this PLC problem-based learning, the focus of learning is on the chosen problem or case so that learning is not only on concepts related to the problem but also on problem-solving. Cadets understand concepts relevant to the problem and gain learning experiences related to skills (Banu, 2020). In current PLC learning, some of the difficulties faced by cadets are: (1) Cadets have difficulty implementing PLC control system applications because the results of the work have not been clearly proven whether the program created is able to run the system correctly and according to the specified criteria; and (2) In applying the control system, cadets create programs with software in the form of simulations so that the ability to assemble and troubleshoot the circuit is not well explored (Abdullah et al., 2021).

Mockups are visual media or previews of a "flat" design concept that are given visual effects so that the results are very visible or resemble the real form. Mockups can provide a real picture of a design concept and how the concept will look good or not good if it has been applied to real objects (Bayramzadeh et al., 2018; De Geetere et al., 2013; dos Santos et al., 2018). With the help of mockup media, it is expected that the problem-based learning process will be more effective because students will get a real picture of the learning material. For example, the subjects of previous studies were vocational students in Pratama et al.'s (2022) research, while in this study, the subjects were TLB cadets who have special competencies in operating and maintaining airport facilities such as airfield lighting system equipment (Kementerian Perhubungan Republik Indonesia, 2021). Due to differences in competencies and characteristics of cadets, it is important to conduct separate research.

Based on previous empirical studies, this research was then conducted by taking a research topic on the effect of problem-based learning models on student learning outcomes by considering

students' initial abilities as a form of student characteristics. Thus, this research will enrich empirical studies on the application of problem-based learning. In addition, the novelty of this research is that it compares problem-based learning with problem-based learning with teaching aids. Learning using teaching aids means optimizing the function of all five senses of students to increase the effectiveness of student learning by hearing, seeing, feeling, and using their minds logically and realistically. This research contributes to the development of project-based learning (PBL) methods that utilize mockup media in the context of programmable logic controller (PLC) learning. Thus, this research can provide a new alternative for educators to present PLC learning materials more interestingly and effectively.

METHOD

This research is a quantitative study using a 2 x 2 factorial design with two-way ANOVA (analysis of variance). The 2 x 2 non-equivalent control group design is one of the quasi-experimental research designs. This study used five variables, namely PBL mockup media (X1), PBL (X2), high initial ability (Z1), low initial ability (Z2), and learning outcomes (Y). Data for variable X was taken from pre-test and post-test scores, initial ability was taken from academic potential test scores, and learning outcomes were taken from cadets' grades.

This research was conducted at the Surabaya Aviation Polytechnic on third-semester cadets of the Diploma Three Airport Electrical Engineering Study Programme. The population and sample in this study were the same, namely 93 people, consisting of 47 cadets of TBL 11AB class as the experimental group of problem-based learning strategy assisted by mockup media and 46 cadets of TLB 12 AB class as the control group of problem-based learning strategy. The sampling technique in this study is to use the simple random sampling method, where each member in the population is carried out or selected randomly without regard to the strata that exist in that population.

The procedure of this study began with collecting data and information from previous studies, making research instruments, testing their validity and reliability, distributing, processing data, and concluding the results. The analysis used two-way ANOVA (analysis of variance) with SPSS application. Data analysis was conducted in two stages, namely, the assumption testing stage and the hypothesis testing stage. The data analysis design is shown in Table 1.

Table 1. Research Design Data Analysis

Variable Attribute (B)	Variable Treatment (A)	Strategy	
		PBL (A ₁)	PBL Media Mock-up (A ₂)
Initial Ability	High (B ₁)	B ₁ A ₁ (22 cadets)	B ₁ A ₂ (26 cadets)
	Low (B ₂)	B ₂ A ₁ (24 cadets)	B ₂ A ₂ (21 cadets)

RESULTS AND DISCUSSION

Results

Data Description

The data description of the initial ability results is that in the experimental class, cadets who have high initial abilities are 26 people, with the highest score of 87 and the lowest score of 70, while those who have low initial abilities are 21 people, with the highest and lowest score of 53. In the control class, cadets who had high ability were 22 people, with the highest score of 91 and the lowest score of 70, while those who had low initial ability were 24 people, with the highest score of 69 and the lowest score of 57. In the control class, the cadets who had high initial ability were 22 people, with the highest score of 91 and the lowest score of 70, while those who had low initial ability were 24 people, with the highest score of 69 and the lowest score of 57.

The data description of the pretest results of the experimental cadet group and the control cadet group was analyzed using the t-test of two independent samples. The calculation results can be seen in Table 2.

Table 2. Calculation of Pretest Result Data

Information	PBL Media Mock Up	PBL
N	47	46
Total score	2774	2636
Rates	59.02	57.30
Variance	53.195	120.394

The data calculation table of the pre-test results with the t-test shows that $t\text{-count} = 0.890 < t\text{-table}$ at a significance level of 0.05 with $df = 91$, namely 1.986, and it is concluded that there is no significant difference in the pre-test results of the experimental class and control class.

Post-test data is obtained from the PLC learning outcomes test at the end of treatment for both groups. The increase in learning outcomes can be seen from the average score. The assumption is that the greater the average score, the higher the improvement in learning outcomes. Conversely, the smaller the average learning outcome, the lower the increase in learning outcomes. The summary of post-test data on learning outcomes is presented in Table 3.

Table 3. Data of Post-test PLC Learning Results

Learning strategies	Initial Ability	Score Maximum	Score minimal	Mean	Standart Deviation	N
PBL Mock Up	High	96	80	85,85	6,763	26
	Low	68	62	74,48	4,686	21
	Total	96	62	80,77	8,189	47
PBL	High	94	80	81,82	6,322	22
	Low	64	58	70,00	6,325	24
	Total	94	58	75,65	8,644	46
Total	High	96	80	84,00	6,804	48
	Low	68	58	72,09	5,999	45
	Total	96	58	78,24	8,757	93

The description of the post-test data of learning outcomes at the end of the treatment of the experimental group and the control group are: (1) the learning outcomes of the experimental class obtained the highest score of 96 and the lowest score of 62, while the control class obtained the highest score of 94 and the lowest score of 58. (2) data on learning outcomes that have high and low initial abilities in the experimental class, students who have high initial abilities from subject (N) 26, the highest score is 96 and the lowest is 80, while those with low initial abilities from subject (N) 21, the highest score is 68 and the lowest is 62. (3) data on learning outcomes of the control class with high initial abilities from subject (N) 26, the highest score is 94, and the lowest is 80, while with low initial abilities from subject (N) 21, the highest score is 64, and the lowest is 58.

Normality Test of Learning Outcomes Data Viewed from Learning Strategy

The normality test of data on learning outcomes of programmable logic controller cadets who received PBL strategy treatment and PBL mockup media was carried out with the Lilliefors Significance Correction test of Kolmogorov-Smirnov and Shapiro-Wilk at the significance level (α) 0.05. The normality test of the dependent variable data distribution can be seen in various ways to get a strong conclusion. In this case, the null hypothesis test (H_0) proposed is that the sample comes from a normally distributed population. Acceptance or rejection of the null hypothesis is based on (1) if the significance value or probability is less than 0.05, the data distribution is abnormal, and (2) if the significance value or probability is more than 0.05, the data distribution is normal.

Calculation of data normality test through Lilliefors Significance Correction test of Kolmogorov-Smirnov and Shapiro Wilk and learning outcomes data with SPSS on the application of mockup learning media and problem-based learning strategies are presented in Table 4.

Table 4. Normality Test Results of Learning Outcomes Data Viewed from Learning Strategy

	Learning Strategy	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
PLC Learning Outcomes	PBL Mock Up	.104	47	.200*	.971	47	.281
	PBL	.119	46	.103	.973	46	.347

The results of the Lilliefors Significance Correction test of Kolmogorov-Smirnov and Shapiro-Wilk can be concluded that by using Kolmogorov-Smirnov both for learning outcomes of problem-based learning media problem-based learning strategy, the average level of significance or probability is above 0.05 (0.200 and 0.103 greater than 0.05), it can be concluded that both data distribution of learning outcomes are normal. Furthermore, using the Shapiro-Wilk test has shown the learning outcomes of both mockup-based learning media and problem-based learning strategies, the level of significance or average probability above 0.05 (0.281 and 0.347 greater than 0.05), it can be concluded that both data distributions of learning outcomes are normal.

Normality Test of Learning Outcome Data Viewed from Initial Ability

From the results of the normality test calculation using the Lilliefors Significance Correction test of Kolmogorov-Smirnov Shapiro - Wilk, the learning outcomes data with the help of the SPSS program, for cadets who have high and low initial abilities are presented in Table 5. Based on the results of the Lilliefors Significance Correction test of Kolmogorov-Smirnov and Shapiro-Wilk in Table 5, it can be concluded that the calculations carried out through the Kolmogorov-Smirnov normality test provide learning outcomes of high and low initial ability with a significance level or probability above 0.05 (0.200 and 0.200 greater than 0.05), obtaining the conclusion that the distribution of the two learning outcomes data based on initial ability is normal. Furthermore, through Shapiro-Wilk for learning outcomes of high and low initial ability, the level of significance or probability is above 0.05 (0.091 and 0.068 greater than 0.05), so it can be concluded that the distribution of the two learning outcomes data is normally distributed.

Table 5. Normality Test Results of Learning Outcomes Data Viewed from Initial Ability

	Initial Ability	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
PLC Learning Outcomes	Hight Initial Ability	.108	48	.200*	.959	48	.091
	Low Initial Ability	.098	45	.200*	.953	45	.068

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Variance Homogeneity Test

The sample variance homogeneity test in this study was carried out on the data of learning outcomes of programmable logic controller cadets who were treated with problem-based learning mockup media and problem-based learning strategies. Test the homogeneity of the sample variance with the Levene test at the 0.05 significance level. Criteria for making decisions on the homogeneity of sample variances can be done by comparing the calculated significance results with a significance level of 0.05. If the calculated significance is more significant than 0.05, it can be concluded that H0 is accepted, so it can be interpreted that the sample variance is homogeneous.

The results of the calculation of the sample variance homogeneity test with the Levene test, learning outcomes data using the SPSS program on the application of mockup media problem-based learning strategies, and problem-based learning strategies are presented in Table 6. The results of the calculation of learning outcomes data with the SPSS computer program obtained the results of the Levene statistic calculation that the level of significance or probability of the average is above 0.05 (0.863 is more significant than 0.05). Likewise, if the basis of measurement is the median data, the significant figure is 0.828, which remains above 0.05. So, H0 is accepted, which means that the sample variance is homogeneous. Based on the results of the two assumption tests, namely the

normality test and the homogeneity test, it can be concluded that the analysis of variance (ANOVA) test can be carried out.

Table 6. Homogeneity Test Results of Learning Outcomes Data Viewed from Learning Strategy

		Levene Statistic	df1	df2	Sig.
PLC	Based on Mean	.030	1	91	.863
	Based on Median	.047	1	91	.828
Learning Outcomes	Based on Median and with adjusted df	.047	1	90.443	.828
	Based on trimmed mean	.027	1	91	.871

Research Hypothesis Test

Hypothesis testing in this study was carried out on the learning outcomes of programmable logic controllers after cadets received learning using a mockup media problem-based learning strategy and a problem-based learning strategy, and the effect of their interaction on high and low initial abilities was seen. This test is conducted to prove the truth of the proposed hypothesis. The hypothesis proposed in this study is that there are differences in learning outcomes of programmable logic controller material between cadets who use mockup media learning strategies with problem-based learning strategies and those who use problem-based learning strategies.

Hypothesis testing in this study was carried out to analyze data on learning outcomes from post-test scores of programmable logic controller material. After the calculation technique of two-way analysis of variance (ANOVA) (two-tailed) at a significance level of 0.05, data processing was carried out using the SPSS computer program with the results presented in Table 7.

Table 7. Two-way Analysis of Variance (ANOVA) Calculation Technique at 5% Significance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3712.900 ^a	3	1237.633	32.960	.000
Intercept	562532.890	1	562532.890	14981.147	.000
Strategy_Strategy	417.552	1	417.552	11.120	.001
Initial Ability	3104.414	1	3104.414	82.675	.000

R Squared = .526 (Adjusted R Squared = .510)

Discussion

The Effect of Learning Strategy on PLC Learning Outcomes

Based on the calculation of the average value, the application of a mockup media problem-based learning strategy has a better effect than the application of problem-based learning on learning outcomes. The average value of mockup media problem-based learning of 80.77 is higher than problem-based learning of 75.65. PLC learning outcomes of students taught using mockup media problem-based learning strategies are higher than the learning outcomes of problem-based learning strategies, these results can be a consideration for lecturers teaching PLC courses to use mockup media problem-based learning strategies in learning.

The two-way ANOVA test obtained a significance value < 0.05 , meaning that the mockup media problem-based learning strategy significantly affects learning outcomes. This is in line with Fidan and Tuncel (2019), who found that the use of media in problem-based learning improves cadets' learning achievement and increases positive attitudes, media technology plays a long-term role in learning concepts. According to Sahronih et al. (2019), the use of media improves learning outcomes; in PLC programming, it is not possible to use complex algorithms; automation control is adapted to the industry (Fuhrländer-Völker et al., 2021).

The learning outcomes of programmable logic controllers achieved by cadets who study with a mock-up media problem-based learning strategy are generally better than problem-based learning strategies. The use of media in problem-based learning strategies produces better output in line with research conducted by Kavlu (2017), Serevina et al. (2018), and R. E. Simamora et al.

(2017). According to Gummineni (2020), learning strategies improve learning outcomes in PLC courses.

The use of different teaching and learning methods, such as paired teaching strategies (Zhang et al., 2023), experimental kits and technology for learning activities (Chookeaw et al., 2019), and project-based learning methods (Seke et al., 2018), have all been shown to improve learning outcomes in PLC courses. These strategies provide students with opportunities to understand difficult concepts, apply knowledge to real-life situations, and engage in hands-on learning experiences. In addition, the use of learning media, such as Controller Circuit Simulator (CCS) (Avianti et al., 2023), is also effective in improving learning outcomes in PLC courses. Overall, the research shows that the application of various learning strategies and technologies can significantly improve learning outcomes in PLC courses.

The Effect of Initial Ability on PLC Learning Outcomes

Overall data analysis found that the average learning outcome for the mockup media problem-based learning strategy was 85.85, and for students with low initial ability, the tendency was 74.48. This shows that students who have high initial ability, on average, have better PLC learning outcomes compared to students who have low initial ability. Then, for the problem-based learning strategy, the average learning outcome of students who have high initial ability is 81.82, and for low initial ability is 70.00.

Based on the test results, the significance value is < 0.05 , meaning that high initial ability has a significant effect on learning outcomes. Kuzmina and Ivanova (2018) had similar findings, namely, the average class achievement was significant and positive for students with high initial ability. In addition to high initial ability, critical thinking skills are also required for PLC programming (Rusimamto et al., 2019). According to Mulyono (2017), learning outcomes are better if an initial ability is controlled using the facilitator and explanatory models. There is no significant difference in the interaction of learning models and academic ability in learning (Rahmat & Chanunan, 2018).

Students with higher initial ability in learning Programmable Logic Controllers (PLCs) perform better compared to students with lower initial ability due to several factors. Firstly, the availability of remedial activities and adaptation of the curriculum based on student outcomes contributed to improved performance (Masco, 2022). These adaptations helped to address deficiencies and provide additional support to students with lower abilities. Secondly, the use of basic logic controller (PLC) programming kits as teaching materials has been shown to improve learning achievement (Llerena-Izquierdo, 2023). These kits allow students to gain hands-on skills and practical experience, which can lead to better understanding and performance in PLC-related tasks.

In addition, the use of laboratory experiments and practical applications of PLCs in various industries can provide students with a healthy learning experience (Kheowsakul et al., 2022). These real-world examples help students connect theoretical concepts with practical applications, leading to improved understanding and performance.

Interaction of Learning Strategy and Initial Ability on PLC Learning Outcomes

The results of the calculation of PLC learning outcomes data to test the hypothesis regarding the interaction effect between learning strategies and initial abilities on learning outcomes obtained significance $\alpha = 0.861$, which is above the significance level of 0.05 ($0.861 > 0.05$). Thus, there is no interaction between learning strategies and initial abilities on PLC learning outcomes. Based on hypothesis testing with a problem-based learning strategy with mock-up media, the average value for cadets who have high initial ability is 84.85; with low initial ability, the average value is 74.47. As for the problem-based learning strategy, the average value of high initial ability is 81.81, and the average value of low initial ability is 70.00.

According to Danial et al. (2017), there is no interaction between learning models and initial abilities, the same opinion was also expressed by Riansyah and Sari (2018). There is no interaction between learning models and academic ability in improving learning outcomes (Rahmat & Chanunan, 2018). According to Davita et al. (2020), the same finding is that there is no interaction between learning strategies and initial abilities in terms of learning outcomes.

The problem-based learning media mock-up learning model is one of the superior learning methods to be applied to cadets in PLC learning, an appropriate learning model used to improve creativity and learning outcomes (Seke et al., 2018). The findings of this study provide vocational education lecturers with insight into how to design interesting learning strategies so that cadets are motivated to learn, and learning outcomes can be achieved well.

CONCLUSION

The mockup media-based learning strategy had a better effect on learning outcomes than the problem-based learning strategy. Learning outcomes met the minimum completion criteria with an average value of problem-based learning treatment assisted by mockup media of 80.77, while the average value of problem-based learning strategy treatment was 75.65. High initial ability obtained better scores than low initial ability in both learning strategies applied (problem-based learning assisted by mockup media and problem-based learning). The average learning outcome of the high initial ability group was 84.00, significantly higher than the cadets who had an average learning outcome of low initial ability of 72.09. There is no significant interaction between learning strategies and the initial ability to learn outcomes of the Programmable Logic Controller (PLC). This study is in line with previous research, which states that learning strategies and initial abilities affect the learning outcomes of cadets. Vocational education cadets need to master learning by using PLC problem-based learning strategies to facilitate the ability to master industrial automation in accordance with actual conditions at the airport. Cadets must be able to adapt to technology that is developing very rapidly. Therefore, learning must be designed with appropriate learning strategies so that cadets understand how PLCs work and are implemented to improve the efficiency and accuracy of industrial processes. This is very important to ensure that industrial processes run according to specified standards, especially at airports.

This research contributes to the development of project-based learning (PBL) methods that utilize mockup media in the context of programmable logic controller (PLC) learning. As such, this research can ensure that engineering and technology education curricula have a high relevance to industry needs. By combining the PBL learning concept and the use of mockup media, students can be better prepared to face the challenges and demands of the industrial world. Although this research can provide valuable insights into the development of learning methods, the long-term impact of using PBL learning with mockup media still needs to be further researched to understand its effects on the quality of education and students' career success.

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