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Project-based learning with cisco packet tracer: effects on students' cognitive domain learning outcomes and critical thinking abillity

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ABSTRACT

This study aims to analyze the effect of Project-Based Learning (PjBL) supported by Cisco Packet Tracer on students' cognitive domain learning outcomes and Critical Thinking Ability (CTA) regarding Local Area Network (LAN) installation. This study employed a quasi-experimental method with a pretest-posttest control group design. The research sample consisted of 120 11th-grade Computer and Network Engineering (CNE) students at SMKN 1 and SMKN 2 Kediri, divided into an experimental group and a control group. The research instruments included 13 multiple-choice questions to measure cognitive learning outcomes and 5 essay questions to measure CTA. Data were analyzed using the independent samples t-test and the paired samples t-test. The results showed that the mean posttest score for cognitive learning outcomes in the experimental group was higher than that in the control group, with scores of 8.42 and 7.40, respectively (p=0.036). The experimental group also demonstrated higher CTA, with scores of 15.08 and 13.77 in the experimental and control groups, respectively (p=0.024). These findings indicate that PjBL assisted by Cisco Packet Tracer is effective in improving students' cognitive learning outcomes and CTA.

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Introduction

Vocational education plays a crucial role in equipping the younger generation with the skills needed to enter the workforce (Alvendri et al., 2023). With the rapid advancement of computer networking technology, Vocational High School (VHS) students are required to master applied competencies, particularly in the field of network installation. This situation calls for a learning approach that not only emphasizes conceptual understanding but also fosters critical thinking and problem-solving skills. One model considered relevant to support these needs is PjBL, as this model integrates the use of technology with real-world problems closely related to students' lives or school-based learning projects (Boleng et al., 2024). In network learning, conceptual understanding is not sufficiently gained through theory alone but must also be supported by practical experience to hone network configuration skills. Therefore, simulation tools can be utilized as interactive learning resources (Aisah, 2025). One widely used software tool is Cisco Packet Tracer, which allows users to design, document, and analyze computer networks virtually without having to rely entirely on physical hardware (Ariyadi & Jordi, 2024). Through this simulation-based approach, students can understand technical concepts more concretely while practicing them directly, especially with material that is difficult to master when learning relies solely on lectures and limited hands-on practice (Henryanto et al., 2025).

Although PjBL has been widely implemented in vocational education to support the mastery of technical skills, previous research findings indicate that the impact of this model on student learning outcomes and CTA has not always been consistent. Several studies indicate that the effectiveness of PjBL can be influenced by various implementation factors, such as limitations in laboratory facilities and teachers' readiness to manage PjBL (Ishayati et al., 2025; Suhaedin et al., 2024). On the other hand, a number of studies also report that PjBL has the potential to improve the quality of learning because it provides a more contextual, meaningful, and student-centered learning experience (Astri et al., 2022; Ati et al., 2024). By engaging students in solving real-world problems, this model is considered capable of supporting improved learning outcomes as well as critical thinking skills as part of 21st-century competencies (Rehman et al., 2024). These findings indicate that PjBL has strong potential for implementation, but its effectiveness still needs to be examined more specifically in accordance with the context of the material, student characteristics, and the learning environment used.

In recent years, PjBL has been widely implemented at various levels of education as a learning strategy focused on active student engagement. Several studies indicate that the implementation of PjBL positively contributes to improved learning outcomes and student motivation (Chaniago & Febrina Dafit, 2024). Other findings suggest that students learning through PjBL achieve higher cognitive and psychomotor learning outcomes compared to those in traditional learning settings (Syaputra et al., 2025). Furthermore, PjBL is also considered effective in fostering the development of CTA, as supported by meta-analysis findings indicating that improvements in students' critical thinking abilities across various educational levels are more effectively achieved through PjBL than through conventional instruction (Tafakur et al., 2023). Similar findings have also been reported in other active learning models, such as REACT, which has been shown to improve student learning outcomes and CTA compared to conventional learning (Haetami et al., 2024). Overall, these findings indicate that student-centered and contextual learning holds great potential for supporting improvements in learning outcomes and CTA.

A number of studies indicate that the implementation of PjBL has the potential to improve student learning outcomes and CTA across various learning contexts. In the context of vocational education, (Desiana et al., 2025) demonstrated that the implementation of PjBL among VHS students can enhance CTA. In terms of learning outcomes, (Setiyowati, 2022) also reported that the implementation of PjBL among VHS students is associated with improved learning outcomes. In network learning, the use of Cisco Packet Tracer has also been reported to have a positive impact on student learning outcomes, particularly regarding basic networking material in VHS (Atjo et al., 2023; Jayadi et al., 2025). Furthermore, the implementation of PjBL in vocational education not only supports the mastery of academic and technical competencies but also contributes to the development of broader skills, such as project management skills (Habibi et al., 2025). However, research specifically integrating PjBL and Cisco Packet Tracer into LAN installation material in VHS remains limited. Furthermore, few studies have simultaneously examined the impact of this integration on students' cognitive learning outcomes and CTA. Therefore, this study aims to address this gap by examining the impact of PjBL assisted by Cisco Packet Tracer on LAN installation material among 11th-grade VHS students.

Based on the above discussion, this study aims to analyze the effect of implementing PjBL supported by Cisco Packet Tracer on students' cognitive learning outcomes and CTA regarding LAN installation in VHS. This study is expected to provide a theoretical contribution to the study of PjBL integrated with simulation media in the context of vocational education. Practically, the results of this study are expected to serve as a reference for teachers in selecting learning strategies capable of strengthening conceptual understanding while developing students' CTA. Thus, the integration of PjBL and Cisco Packet Tracer is expected to provide a more contextual, interactive, and relevant learning alternative to meet the needs of network learning in VHS.

Method

This study employed a quantitative approach using a quasi-experimental design of the pretest-posttest control group type. The study was conducted during the even semester of the 2025/2026 academic year, specifically from January to February 2026, at SMKN 1 Kediri and SMKN 2 Kediri. The research locations were selected using purposive sampling, specifically choosing schools that offer a Computer and Network Engineering (CNE) program. All 11th-grade CNE students at both schools were included as the research sample, resulting in total sampling of the accessible population of 120 students. The experimental and control groups were determined based on the classes that had already been formed at each school.

The research instruments consisted of a cognitive domain learning achievement test and a CTA test. The cognitive domain learning achievement test comprised 13 multiple-choice questions designed based on Bloom's revised taxonomy at levels C1–C4, while the CTA test comprised 5 essay questions developed based on

Facione's critical thinking indicators. Before being used in the study, all instruments were first pilot-tested on 15 students outside the study sample. The pilot test data were then analyzed using SPSS to assess the validity and reliability of the instruments. Based on the results of this analysis, the instrument items that met the validity and reliability criteria were used in the study. The item lists for both instruments are presented in Table 1, while the scoring rubric for the CTA test is presented in Table 2.

Table 1. Instrument Outline for Cognitive Domain Learning Outcomes and Critical Thinking Ability.

A. Cognitive Domain Learning Outcomes			
Main Topics	**Cognitive Level**	**Question Indicator**	**Question Number**
Basic Networking Concepts	C1 (Remembering)	Identify the definition of a computer network	1
	C2 (Understanding)	Classify network types of based on range	2
Network Topology	C1 (Remembering)	Identify types of network topologies	3
		Describe the characteristics of a bus topology	4
	C2 (Understanding)	Compare two network Topologies	5
	C3 (Applying)	Determine the topology that best suits network needs	6
IP Addresses	C2 (Understanding)	Explain the difference between public and private IP addresses	7
		Explaining the differences between IPv4 and IPv6	8
	C3 (Applying)	Determining IP address classes	9
		Calculating the number of hosts in a network	10
	C4 (Analyzing)	Analyzing IP address configuration errors	11
LAN Network	C1 (Remembering)	Identifying LAN network devices	12
	C3 (Applying)	Determining the appropriate use of network devices based on needs	13
B. Critical Thinking Ability			
Main Topics	**Dimensions**	**Question Indicator**	**Question Number**
Basic Networking Concepts	Interpretation	Interpret network issues based on given conditions	1
Network Topology	Evaluation	Evaluate the suitability of network topologies for specific needs	2
IP Addresses	Analysis	Analyzing IP address conflicts and determining how to resolve them	3
IP Addresses	Explanation	Explain the technical causes of network issues	4
LAN Network	Inference	Draw conclusions and propose solutions for local network issues	5

The study began with the administration of a pretest to the experimental and control groups. Subsequently, for two months, the experimental group received instruction using PjBL supported by Cisco Packet Tracer, while the control group received conventional instruction. After the treatment period ended, both groups were given a posttest. The research data were analyzed using SPSS through validity and reliability tests, descriptive statistics, normality tests, homogeneity tests, independent samples t-tests, and paired samples t-tests. This analytical procedure facilitates an accurate evaluation of the effectiveness of the PjBL model using Cisco Packet

Tracer simulations in relation to students' cognitive learning outcomes and CTA. The conceptual framework underlying the entire research process can be seen in Figure 1.

Table 2. Critical Thinking Ability Rubric

Skor	Kriteria Penilaian
4	Jawaban benar, lengkap, dan terstruktur dengan baik, sesuai dengan konsep jaringan komputer, serta disertai alasan logis yang relevan dengan permasalahan.
3	Jawaban benar dan relevan, tetapi penjelasan atau alasan yang diberikan tidak lengkap.
2	Jawaban sebagian benar, tetapi tidak sepenuhnya akurat atau kurang memiliki alasan yang jelas.
1	Jawaban tidak akurat atau sangat terbatas, serta tidak menunjukkan pemahaman terhadap konsep.
0	Tidak ada jawaban yang diberikan, atau jawaban tidak relevan dengan pertanyaan.

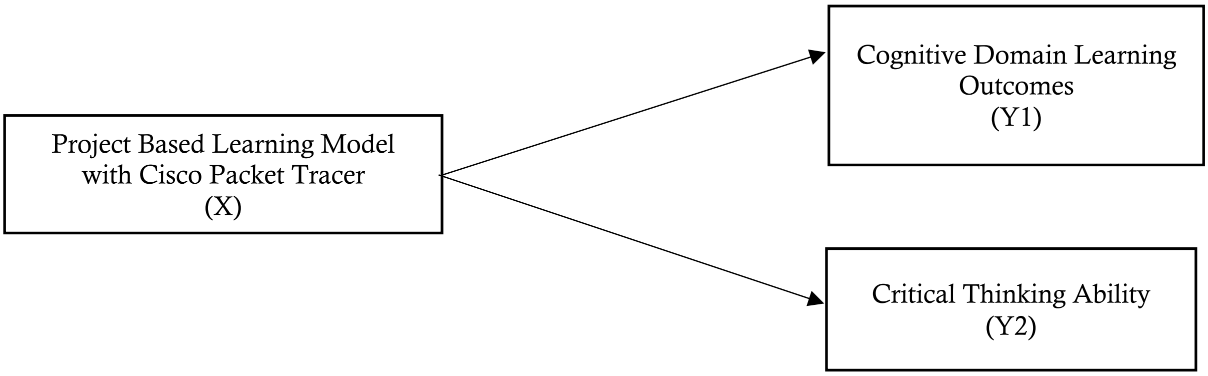

Figure 1. Conceptual Framework.

Results and Discussions

Validity indicates the degree to which an instrument accurately measures the aspects it is intended to measure (Friska Aryanti et al., 2024). In this study, validity testing was conducted using Pearson's Product-Moment correlation, with items deemed valid if the calculated r value was greater than the table r value or the significance level was less than 0.05. Reliability indicates the degree of consistency of an instrument when used repeatedly under relatively similar conditions (Friska Aryanti et al., 2024). In this study, reliability was assessed using Cronbach's Alpha, with an instrument deemed reliable if the coefficient was greater than 0.60.

Table 3. Reliability Coefficient of the Research Instrument.

Cronbach's Alpha	N of Items
0.615	18

Based on the test results in Table 3 and Table 4, the research instrument, consisting of 18 items, 13 items for cognitive domain learning outcomes and 5 items for CTA, was deemed valid and reliable. All items in the instrument had a correlation value above the critical value of $r = 0.178$, while the reliability test results showed a Cronbach's Alpha value of 0.615. Thus, the entire instrument was deemed suitable for use in the study.

Table 4. Validity Assessment of the Research Instrument Items.

No.	Corrected Item-Total Correlation	Interpretation (Item Validity)
Item 1	0.409	Valid
Item 2	0.404	Valid
Item 3	0.447	Valid
Item 4	0.423	Valid
Item 5	0.310	Valid
Item 6	0.483	Valid
Item 7	0.554	Valid
Item 8	0.312	Valid
Item 9	0.441	Valid
Item 10	0.255	Valid
Item 11	0.598	Valid

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No.	Corrected Item-Total Correlation	Interpretation (Item Validity)
Item 12	0.388	Valid
Item 13	0.462	Valid
Item 14	0.792	Valid
Item 15	0.779	Valid
Item 16	0.842	Valid
Item 17	0.815	Valid
Item 18	0.827	Valid

Table 5 and Table 6 present the results of the descriptive statistical analysis, which include the means and Standard Deviations (SD) of the pretest and posttest scores for the control group and the experimental group.

Table 5. Descriptive Statistics of Cognitive Domain Learning Outcomes.

Group	Pretest		Posttest	
	Mean	SD	Mean	SD
Control	6.20	2.349	7.40	2.499
Experiment	6.30	2.367	8.42	2.733

Based on Table 5, the mean pretest score for cognitive domain learning outcomes in the control group was 6.20 (SD = 2.349), while in the experimental group it was 6.30 (SD = 2.367). After the intervention was administered, the posttest mean in the control group increased to 7.40 (SD = 2.499), while in the experimental group it increased to 8.42 (SD = 2.733). These results indicate that both groups experienced an improvement in cognitive domain learning outcomes, with the experimental group achieving a higher posttest mean compared to the control group.

Table 6. Descriptive Statistics of Critical Thinking Ability.

Group	Pretest		Posttest	
	Mean	SD	Mean	SD
Control	8.95	2.317	13.77	2.982
Experiment	10.33	2.685	15.08	3.321

Based on Table 6, the pretest mean for CTA in the control group was 8.95 (SD = 2.317), while in the experimental group it was 10.33 (SD = 2.685). On the posttest, the control group's mean increased to 13.77 (SD = 2.982), while the experimental group's increased to 15.08 (SD = 3.321). These findings indicate an improvement in CTA in both groups, with the experimental group achieving a higher posttest mean than the control group.

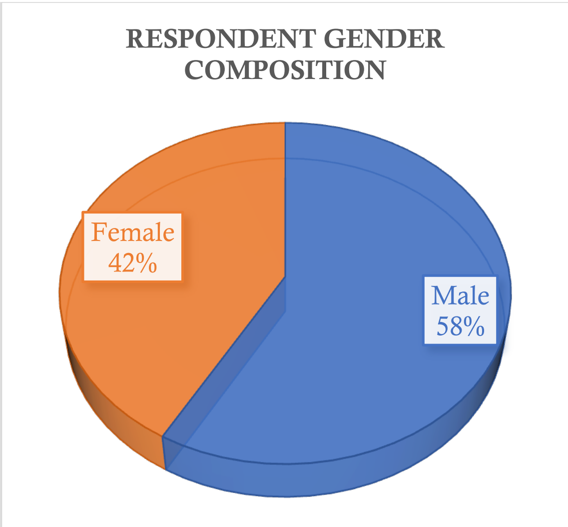

Figure 2. Gender Distribution.

This pie chart illustrates the demographic composition of respondents, with male students accounting for 58% of the sample (70 students), while female students represent 42% (50 students). These findings indicate that the male sample is larger than the female sample.

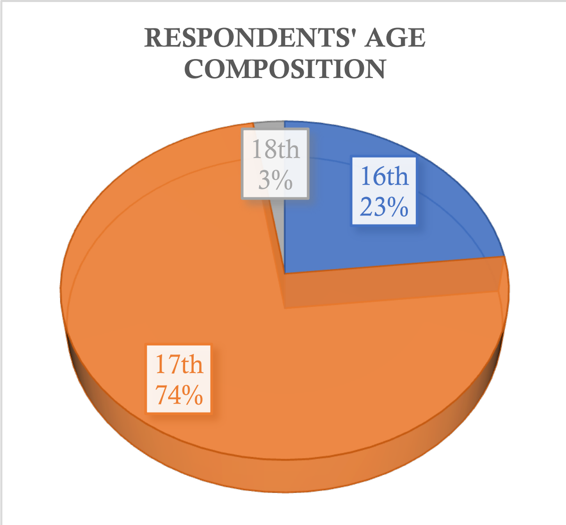

Figure 3. Age Distribution.

As shown in the diagram, the demographic distribution of respondents indicates that the dominant age group is 17 years old, representing 23% (28 students), while the 18-year-old age group represents only 3% (3 students). A normality test is conducted to determine whether the research data is normally distributed (Toedien et al., 2025). In this study, the Kolmogorov–Smirnov test was used because the sample size was 120 students. The data were considered normally distributed if the Asymp. Sig. (2-tailed) value was greater than 0.05.

Table 7. Results of Cognitive Domain Data Normality Analysis.

Group	Test Type	Sig.	Interpretation
Control	Pre-test	0.200	Normal Distribution
	Post-test	0.180	Normal Distribution
Experimental	Pre-test	0.200	Normal Distribution
	Post-test	0.200	Normal Distribution

Table 8. Results of Critical Thinking Ability Data Normality Analysis.

Group	Test Type	Sig.	Interpretation
Control	Pre-test	0.200	Normal Distribution
	Post-test	0.200	Normal Distribution
Experimental	Pre-test	0.200	Normal Distribution
	Post-test	0.199	Normal Distribution

Based on the results of the normality test in Table 7 and Table 8, all pretest and posttest data in both the control and experimental groups showed an Asymp. Sig. (2-tailed) value above 0.05. Regarding cognitive domain learning outcomes, the significance values for the control group were 0.200 for the pretest and 0.180 for the posttest, while for the experimental group, they were 0.200 for both the pretest and posttest. Regarding CTA, the significance values in the control group were 0.200 for both the pretest and posttest, while in the experimental group, they were 0.200 for the pretest and 0.199 for the posttest. Thus, all research data were found to be normally distributed.

A homogeneity test is used to determine whether the data in each group have equal variances, or are homogeneous (Toedien et al., 2025). In this study, the Levene test was used for the homogeneity test, with the criterion that the data were considered homogeneous if the significance value was greater than 0.05.

Table 9. Testing the Homogeneity of Variance in Cognitive Domain Learning Outcomes Data.

Levene Statistic	df1	df2	Sig.
0.834	1	118	0.363

Table 10. Test of Homogeneity of Variance of Critical Thinking Ability Data.

Levene Statistic	df1	df2	Sig.
1.595	1	118	0.209

Based on the results of the homogeneity test, the cognitive domain learning outcome data yielded a significance value of 0.363, while the CTA data yielded a significance value of 0.209. Since both values are greater than 0.05, the data variance is deemed homogeneous. To statistically analyze the variation in average scores between the two groups in relation to cognitive achievement and CTA, this study used the Independent Samples t-Test as the method of analysis.

Table 11. Independent Sample t-Test Analysis Between Experimental and Control Groups.

Variable	Class	N	Mean	SD	Std. Error Mean
Cognitive Domain Learning Outcomes	Control	60	7.40	2.499	0.323
	Eksperimen	60	8.42	2.733	0.353
Critical Thinking Ability	Kontrol	60	13.77	2.982	0.385
	Eksperimen	60	15.08	3.321	0.429

Table 12. Independent Sample t-Test Results for Cognitive Domain Learning Outcomes and Critical Thinking Ability

Information		T	df	Sig.	Decision
Cognitive Domain Learning Outcomes	Equal variances assumed	-2.127	118	0.036	There is a significant difference
	Equal variances not assumed	-2.127	117.068	0.036	There is a significant difference
Critical Thinking Ability	Equal variances assumed	-2.285	118	0.024	There is a significant difference
	Equal variances not assumed	-2.285	116.662	0.024	There is a significant difference

Based on the results of the independent samples t-test, there was a significant difference between the control group and the experimental group in learning outcomes in the cognitive domain and CTA. In learning outcomes in the cognitive domain, the control group scored an average of 7.40 (SD = 2.499), while the experimental group scored an average of 8.42 (SD = 2.733). Regarding CTA, the control group achieved a mean of 13.77 (SD = 2.982), while the experimental group achieved a mean of 15.08 (SD = 3.321). These differences were statistically significant, with a p-value of 0.036 for cognitive domain learning outcomes and 0.024 for CTA. Thus, the experimental group demonstrated better performance than the control group on both research variables. The distribution of the achievement levels of these two variables can be seen in Figure 4.

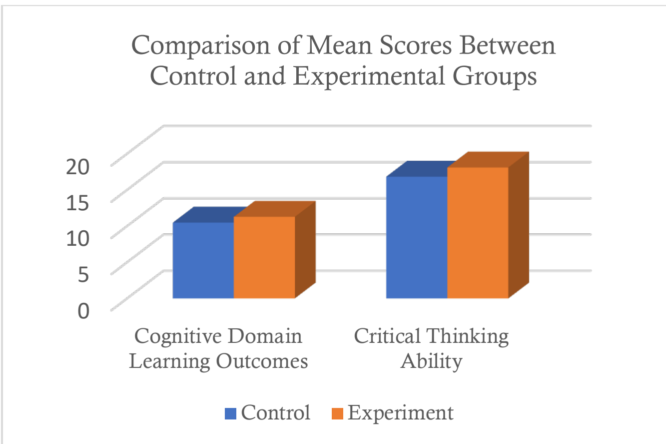

Figure 4. Independent Sample t-Test Distribution.

The Paired Sample T-test was employed to evaluate mean discrepancies between two correlated data sets. In this study, pretest-posttest data from the experimental class were used to measure both cognitive domain learning outcomes and CTA.

Table 13. Analysis of Pre-test and Post-test Differences Using the Paired Sample t-Test.

Variable	Class	N	Mean	SD	Std. Error Mean
Cognitive Domain Learning Outcomes	Eksperimental Pretest	60	6.30	2.367	0.306
	Eksperimental Posttest	60	8.42	2.733	0.353
Critical Thinking Ability	Eksperimental Pretest	60	10.33	2.685	0.347
	Eksperimental Posttest	60	15.08	3.321	0.429

Table 14. Paired Sample t-Test Results for Cognitive Domain Learning Outcomes and Critical Thinking Ability.

Information		T Test for Equality of Means		
		T	df	Sig. (2-tailed)
Cognitive Domain Learning Outcomes	Pretest-Posttest Experimental Class	-4.753	59	0.000
Critical Thinking Ability	Pretest-Posttest Experimental Class	-8.009	59	0.000

The results of the paired-sample t-test indicated that there was a significant difference between pretest and posttest scores in the experimental group, both in cognitive domain learning outcomes and CTA. The mean cognitive domain learning outcomes increased from 6.30 (SD = 2.367) on the pretest to 8.42 (SD = 2.733) on the posttest. Meanwhile, the mean CTA increased from 10.33 (SD = 2.685) to 15.08 (SD = 3.321). The test results showed a significance value of 0.000 for both variables, leading to the conclusion that instruction in the experimental group resulted in a significant improvement in students' cognitive domain learning outcomes and CTA. The distribution of achievement levels for both variables is presented in Figure 5.

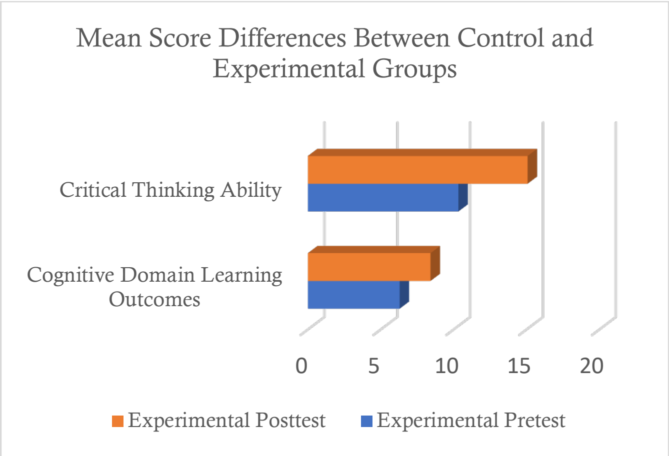

Figure 5. Paired Sample t-Test Distribution.

The results of the study indicate that the implementation of PjBL supported by Cisco Packet Tracer has a positive impact on students' cognitive learning outcomes and CTA regarding LAN installation. These findings not only demonstrate a difference in achievement between the experimental and control groups but also confirm that integrating a PjBL model with network simulation tools fosters a more active, contextual, and meaningful learning process.

The improvement in cognitive domain learning outcomes in the experimental group can be attributed to the characteristics of PjBL, which positions students as active participants in the learning process. In this model, students do not merely passively receive information but are actively engaged in understanding problems, planning steps, running simulations, and evaluating the results obtained. These activities allow students to move from the process of remembering and understanding toward applying and analyzing, as reflected in cognitive levels C1 through C4 in this research instrument. Thus, the improvement in cognitive learning outcomes is not only due to exposure to the material but also to students' engagement in deeper thinking processes while completing network tasks or projects.

In the context of LAN setup, the use of Cisco Packet Tracer enhances the process by helping students visualize abstract networking concepts in a more concrete way. Through simulation, students can see the connections between devices, test network configurations, and directly observe the results of their actions. This is crucial because networking concepts cannot be fully grasped through theory alone, they must be learned through hands-on practice that allows students to connect concepts with their practical applications. This function aligns with the nature of Cisco Packet Tracer as software that can be used to design, configure, and simulate computer networks practically without having to rely entirely on physical hardware. Therefore, the combination of PjBL and Cisco Packet Tracer makes learning more interactive and helps students build a stronger understanding of LAN installation material.

In terms of CTA, the improvement observed in the experimental group can be attributed to the types of learning activities conducted during the lesson. In PjBL using Cisco Packet Tracer, students were presented with tasks that required them to interpret network problems, assess the accuracy of topologies or configurations, explain technical reasons, and draw conclusions regarding the chosen solutions. This process aligns with the aspects of critical thinking used in this study, namely interpretation, evaluation, explanation, and drawing conclusions. In other words, CTA develop not only because students work on projects, but because these projects require analysis of real-world problems and decision-making supported by technical reasoning.

In the LAN installation module, the development of CTA is particularly relevant because students are not only expected to understand networking concepts but also to determine solutions to problems such as selecting a topology, configuring IP addresses, identifying IP conflicts, and evaluating appropriate networking devices. The research essay instrument also indicates that students are required to interpret network problems, assess the suitability of topologies, correct configuration errors, and conclude on the appropriate solution. Activities like these encourage students to use systematic reasoning, so that learning does not stop at mastering procedures but develops into the ability to evaluate, explain, and decide on solutions logically. This explains why the experimental group achieved higher critical thinking scores compared to the control group.

The findings of this study are consistent with previous research indicating that PjBL positively contributes to improved student learning outcomes and CTA. (Agus & Efriyanti, 2023) demonstrated that PjBL can enhance student learning outcomes, while (Erni et al., 2024) confirmed that the implementation of PjBL fosters more active learning and has a positive impact on learning achievements. Regarding critical thinking ability, the findings of this study also align with (Hasnidar & Susanti, 2025), who state that PjBL can enhance

CTA through more interactive learning, as well as (Nadiyah & Tirtoni, 2023), who emphasize that PjBL provides students with opportunities to develop CTA more concretely through active engagement in the learning process. However, this study provides a more specific confirmation because the improvement in cognitive domain learning outcomes and CTA occurred in the context of LAN installation at VHS with the support of Cisco Packet Tracer as a simulation medium. Thus, the integration of PjBL and Cisco Packet Tracer not only supports active learning but also strengthens the connection between conceptual understanding, technical practice, and real-world network problem-solving.

Conclusions

This study shows that the implementation of Project-Based Learning supported by Cisco Packet Tracer has a positive effect on students' cognitive learning outcomes and critical thinking ability regarding local area network installation at vocational high schools. These findings confirm that integrating PjBL with simulation tools not only helps students understand network concepts and procedures more concretely but also encourages them to analyze problems, evaluate solutions, and make decisions more logically within a technical learning context. Nevertheless, this study has several limitations. The research was conducted at only two schools, focused on a single learning topic, namely LAN installation, and was carried out over a relatively short intervention period. Therefore, the results of this study should be understood within the context of the research and cannot be broadly generalized without considering different school conditions, learning materials, and instructional durations. Practically, the results of this study indicate that vocational teachers, particularly in the field of computer networking, can integrate Cisco Packet Tracer into PjBL learning to support conceptual understanding, configuration practice, and more contextual network problem-solving. This integration can serve as an alternative learning strategy for technical subjects that require higher-order thinking skills and hands-on experience.

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