Journal of Learning Improvement and Lesson Study
Volume 6 Number 1 2026, pp, 1-12
E-ISSN: 2798-9011
DOI: 10.24036/jlils.v6i1.213
Received April 18, 2026; Revised May 31, 2026; Accepted June 1, 2026
Availaible Online: https://jlils.ppj.unp.ac.id

Can Inquiry-Based Learning Effectively Improve Vocational High School Students' Critical Thinking and Conceptual Understanding?

Ghanifa Khoirul Khasanah[1*], Nurhening Yuniarti[1], Irdayanti Binti Mat Nashir[2]

[1] Universitas Negeri Yogyakarta, Sleman, Indonesia
[2] Universiti Pendidikan Sultan Idris, Perak, Malaysia
*Corresponding, e-mail: ghanifakhoirul.2022@student.uny.ac.id

Abstract
Modern industrial demands require vocational students to possess high-level analytical skills, making existing conceptual gaps in fundamental engineering laws a critical challenge. This study evaluates Inquiry-Based Learning in improving critical thinking and conceptual understanding of Ohms Law. While the Wilcoxon Signed-Rank Test measures within-group shifts, this quasi-experimental study utilizes a two-stage cluster random sampling technique and applies the Mann-Whitney test to compare cross-group gains among seventy-two participants. Data gathered via multiple-choice and analytical essay instruments revealed significant post-intervention gains favoring the inquiry class, further validated by a large experimental effect size value of minus zero point five rather than a solitary probability metric. Structured scientific inquiry effectively bridges abstract electrical theory with robust diagnostic competencies, prompting researchers to reconsider how statistical gain comparisons can definitively reshape traditional, lecture-based regimes in technical education.

Keywords: Inquiry-Based Learning, Critical Thinking, Conceptual Understanding, Basic Electrical, Vocational Education.

This is an open access article distributed under the Creative Commons Attribution-ShareAlike 4.0 International License.
©2021 by author

Introduction

Modern industrial demands have forced a significant shift in how vocational education prepares its students. Vocational High Schools (SMK) are no longer just places to learn manual tasks but must function as centers for developing 21st-century competencies (Nuryanto & Eryandi, 2020). National curricula now prioritize the mastery of complex skills to help students navigate the disruptive era characterized by rapid technological change (Rahimi & Oh, 2024). Students need strong critical thinking abilities to troubleshoot intricate industrial systems and adapt to unpredictable workplace challenges (Warsi et al., 2024). This urgency is directly supported by the Program for International Student Assessment 2022 report from the OECD. The data shows that Indonesian students obtained a science literacy score of 383 and a mathematics score of 366. Both achievements are significantly below the OECD average scores, which stand at 485 for science and 472 for mathematics. These results place Indonesia in 67th position out of 81 participating countries, indicating a substantial gap in higher-order thinking skills (OECD, 2023). Scientific literacy levels remain a primary concern for educators aiming to meet international benchmarks (Kumar & Choudhary, 2024).

Low scientific literacy poses a severe threat to technical disciplines such as electrical engineering. Electrical students must possess a deep conceptual understanding of fundamental physical laws to perform their duties safely and effectively (Li & Guo, 2021). Ohm's Law serves as the core foundation for all subsequent learning in power systems and circuit analysis (Salah, 2025). Mastery of the relationship between voltage, current, and resistance is essential for any practical application in the field (Aarkrog, 2022). Many vocational learners struggle to move beyond simple memorization of mathematical formulas (Sehole et al., 2023). Failure to internalize these concepts prevents students from solving real-world technical problems when they enter the industry (Rachmad, 2023).

Effective conceptual mastery in technical subjects requires instructional models that challenge students to synthesize information through various forms of discourse. Multi-representation discourse models facilitate the development of critical thinking by requiring students to translate abstract ideas into concrete visual, graphical, and mathematical forms (Adnyana et al., 2021). Logical reasoning improves when students are forced to explain the "why" behind an electrical phenomenon rather than just calculating a result. Deep conceptual understanding emerges as students engage in multi-representational problem-solving, allowing them to see the underlying structure of technical principles (Widiyanti et al., 2022). This discursive approach provides a cognitive bridge that enables learners to evaluate complex data and make informed technical decisions.

Initial observations conducted on January 5, 2026, in class X TKL A (Electrical Power Engineering program) during the Electrical Measurement course, revealed clear pedagogical and structural gaps at SMK Negeri 1 Sedayu. This initial data collection involved a single class of 36 students and one subject teacher, utilizing direct classroom observation alongside structured interviews as the primary techniques. Through these methods, it was found that lessons often focus on theoretical lectures followed by repetitive written exercises (Dietrich & Evans, 2022). Passive learning environments limit the development of students' analytical minds (Loyens et al., 2023). The empirical evidence of the problem was particularly evident during practical sessions, which suffered from a severe shortage of laboratory equipment. In this specific class, thirty-six students had to share only three functioning measuring instruments, forcing the majority to rely on passive viewing rather than hands-on experimentation (Sabur et al., 2023). This disconnection between classroom theory and industrial reality becomes more pronounced when students cannot experiment freely (Harleni et al., 2025). Vocational graduates continue to face high unemployment rates due to a lack of the analytical skills required by modern employers (Kovalchuk et al., 2022).

Inquiry-Based Learning (IBL) provides a robust framework to address these pedagogical deficiencies. This model shifts the focus from receiving information to active investigation (Sam, 2024). Students in an inquiry-based classroom act as researchers who must define problems and formulate their own hypotheses (Safkolam et al., 2024). Structured investigation helps learners reconcile their prior misconceptions with empirical evidence (Sam, 2024). Evidence suggests that active engagement with scientific data leads to a more permanent understanding of technical concepts (Fitrianto & Saif, 2024). Critical thinking skills are systematically enhanced through the requirement to justify conclusions based on experimental evidence, as this process stimulates high-level cognitive evaluation and logical reasoning (Fitrianto & Saif, 2024).

Implementing a deep learning approach through inquiry requires a careful balance between scientific exploration and technical accuracy. A mapping of previous literature reveals a significant imbalance in the application of this model. While extensive research has validated the effectiveness of Inquiry-Based Learning (IBL) in general science education at the secondary school level (Rushton et al., 2023), its exploration within vocational high schools (SMK) remains highly limited. Furthermore, existing vocational studies predominantly focus on non-technical competencies or general engineering motivation. What remains unresearched is the specific intersection of IBL implementation within specialized electrical engineering courses, particularly regarding the mastery of fundamental conceptual and practical laws such as Ohm's Law in resource-constrained environments. Vocational students have unique learning needs because they must meet rigorous industrial competency standards (Tadesse et al., 2025). Addressing this research gap is vital for improving the quality of technical education in the region (Sabur et al., 2023). Effective instructional models must be tested in real-world, resource-constrained environments (Bartolomé, 2026).

This study evaluates the effectiveness of the Inquiry-Based Learning model in improving critical thinking and conceptual understanding of Ohm's Law at SMK Negeri 1 Sedayu. The investigation focuses on whether a structured inquiry approach allows students to interpret electrical data more effectively than traditional methods. Findings are expected to provide practical guidance for vocational teachers on how to create more interactive learning environment. Scientific inquiry can serve as a bridge between educational policy and actual classroom practice. This research ultimately seeks to support the development of a more analytical and competent vocational workforce.

Method

The study employed a quantitative approach using a quasi-experimental design, specifically the Pretest-Posttest Control Group Design, to examine the influence of Inquiry-Based Learning (IBL) on student outcomes. Research was conducted at SMK Negeri 1 Sedayu from January to March 2026, targeting Tenth-Grade students in the Electrical Power Engineering program. The population comprised three parallel Tenth-Grade classes within this specialization. The sample was determined through a two-stage cluster random sampling procedure. In the first stage, out of the three available classes, two classes were randomly selected using a lottery method to ensure every cluster had an equal probability of inclusion. In the second stage, another random draw was performed to assign the roles of the selected clusters; Class X TKL A was designated as the experimental group (n = 36) and Class X TKL B as the control group (n = 36), totaling 72 participants. Since the initial academic data did not meet the assumption of normal distribution, a non-parametric Mann-Whitney U Test was performed on the students' prior academic records from the preceding semester to establish baseline equivalence. The analysis confirmed no statistically significant difference in initial competence between the experimental and control groups ($p > 0.05$), validating their suitability for comparison.

The investigation focused on the Ohm's Law module within the Electrical Measurement course, delivered over three 180-minute sessions per class. Session 1 established baseline parameters via a pretest. Session 2 deployed the core interventions: the experimental class executed inquiry-based circuit experiments, while the control class received conventional teacher-centered instruction and problem-solving drills. Session 3 concluded the process with a posttest to evaluate cognitive shifts. To guarantee treatment fidelity, a senior vocational teacher utilized a standardized observation checklist during the second session to verify that the experimental class adhered strictly to the IBL syntax while the control class maintained conventional pedagogy.

The assessment of student outcomes was structured around specific indicators derived from established theoretical frameworks. Critical thinking skills were evaluated using Ennis's (2011) taxonomy, which aligns with technical diagnostic requirements by operationalizing five cognitive dimensions for troubleshooting: elementary clarification to identify electrical faults, basic support to assess multimeter data, inference to determine circuit behavior, advanced clarification to test argument consistency, and strategies and tactics for safe engineering decisions. Simultaneously, conceptual mastery of Ohm's Law was operationalized through Anderson & Krathwohl (2001) revised Bloom's Taxonomy to prioritize cognitive restructuring over rote memory. This framework evaluated technical competence across critical dimensions, measuring the students' capacity to interpret electrical principles in personal terminology, classify electrical objects by attributes, differentiate between circuit examples and non-examples, and execute technical procedures to solve real-world engineering problems.

The experimental group followed the five IBL stages (orientation, hypothesis generation, data collection, data analysis, and conclusion drawing), while the control group received conventional lectures and guided practice. Conceptual understanding was measured via a validated 20-item multiple-choice test, whereas critical thinking was evaluated using an analytical essay test. Both instruments underwent expert content validation and empirical reliability testing prior to implementation. Essay responses were scored from 0 to 4 using an analytical rubric based on critical thinking indicators (interpretation, analysis, evaluation, and inference). The specific scoring tiers and operational descriptors used to evaluate this critical thinking essay test are detailed in Table 1.

Table 1. Analytical Scoring Rubric for Critical Thinking Essay (Scale 0–4)

Score	Operational and Technical Description
4	Synthesizes circuit topologies precisely, deconstructs systemic anomalies systematically, and formulates exhaustive causal rationales for parameter interdependencies (Voltage, Circuit, Resistance).
3	Evaluates datasets rigorously and derives valid inferences from empirical measurements, though minor structural nuances in the explanation of causal mechanisms lack absolute comprehensiveness.
2	Articulates fundamental electrical doctrines correctly but exhibits superficial analytical reasoning, merely cataloging raw empirical data without establishing robust evaluative frameworks or profound inferences.
1	Demonstrates fragmented cognitive processing, fails to distinguish rudimentary data patterns, omits critical empirical validation, and presents highly flawed technical diagnostic conceptualizations.
0	Exhibits total cognitive non-engagement by rendering no written response, leaving the examination protocol blank, or submitting answers that diverge entirely from the technical parameters.

Applying this analytical rubric transformed qualitative engineering justifications into precise, objective numerical data. Two independent raters evaluated the essay scripts simultaneously to eliminate scoring bias and ensure high inter-rater reliability. Minor scoring discrepancies were resolved through collaborative session reviews until an absolute consensus was reached. Data collection occurred in two distinct chronological phases: a pretest to establish baseline equivalence and a posttest to measure cognitive gains. These test baselines provided the complete dataset required to analyze the overall instructional efficacy of the pedagogical intervention.

Data analysis began with descriptive statistics to summarize mean scores and variance. Diagnostic tests for normality and homogeneity were performed; since the data violated normality assumptions, the Wilcoxon Signed-Rank Test was utilized as the primary inferential statistic. This non-parametric test determined the significance of changes between pretest and posttest results for both groups. The methodology assumes that student attendance and prior knowledge across groups remained consistent throughout the intervention. By strictly limiting the scope to critical thinking and conceptual mastery, this study ensured a focused evaluation of the IBL model's effectiveness in a technical vocational context.

Table 2. Quasi-Experimental Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	-	O_4

Table 2 provides a systematic overview of the comparative research framework applied in this study. The experimental group is represented by the initial observation (O1), followed by the implementation of the Inquiry-Based Learning model (X), and concluded with a final observation (O2). Correspondingly, the control group underwent initial and final observations (O3 and O4) while receiving conventional instruction (-) as a baseline for comparison. This structure allows for a clear measurement of the treatment's impact by comparing the gain scores between the two independent groups.

Results and Discussion

The empirical results of this study, conducted at SMK Negeri 1 Sedayu, demonstrate a transformative advancement in students' cognitive outcomes following the implementation of Inquiry-Based Learning (IBL). By utilizing a Pretest-Posttest Control Group Design, the study provides clear evidence of how the IBL intervention (X) specifically addresses the research questions posed in the introduction. The findings move the reader's understanding forward by proving that IBL is not merely an alternative instructional method but a functional necessity for fostering industry-ready analytical skills in vocational students.

This pedagogical requirement becomes empirically observable when analyzing the quantitative shifts between the initial baselines and the subsequent post-intervention measurements. Standard statistical evaluations of this quasi-experimental design indicate a pronounced variance in critical thinking gains, suggesting that the inquiry framework fosters more robust cognitive adaptation than the conventional setup. However, interpreting these numerical trends as absolute confirmation of pedagogical causation requires methodological prudence due to inherent threats to internal validity. The lack of random participant assignment across the intact vocational classes implies that confounding variables, such as variations in baseline aptitude or preexisting student motivation, could partially influence the final outcomes. Isolating the instructional model as the definitive catalyst for these advanced troubleshooting skills would therefore require triangulation through diagnostic misconception data, student interviews, or longitudinal classroom observations.

1. The Effectiveness of Inquiry-Based Learning in Enhancing Critical Thinking Skills

The shift toward an inquiry-based framework required students to navigate complex problem-solving scenarios that challenged their initial cognitive assumptions regarding electrical circuits. By engaging in systematic observation and evidence-based reasoning, learners were prompted to synthesize theoretical knowledge with practical measurement outcomes. This pedagogical transition aimed to stimulate the higher-order thinking skills necessary for troubleshooting unpredictable technical anomalies. This approach allowed the classroom environment to evolve from a teacher-led lecture into a collaborative laboratory where students actively validated hypotheses. Such an investigative atmosphere was crucial for fostering the intellectual independence that characterizes advanced critical thinking. The following statistical analysis provides a quantitative reflection of how these instructional changes manifested in the students' overall analytical performance.

The implementation of Inquiry-Based Learning (IBL) in this study was designed to transition students from passive learners to active investigators of electrical phenomena. To determine whether this model significantly impacted the students' analytical capabilities, a Mann-Whitney Test was conducted. This non-parametric analysis was selected due to the non-normal distribution of the pretest and posttest data within the experimental group. The statistical results for the experimental class are presented in Tables below.

Table 3. Shapiro-Wilk Normality Test Results on Students' Critical Thinking Skills

Test of Shapiro-Wilk Normality				
Group Name	**Statistic**	**N**	**Significance (p-value)**	**Distribution Status**
Experimental Class	0.638	36	<0.001	Not Normally Distributed
Control Class	0.823	36	<0.001	Not Normally Distributed

Table 3 presents the empirical results of the Shapiro-Wilk normality test, which evaluated the distribution of critical thinking skill scores across both the experimental and control classes. This statistical diagnostic is essential for determining whether the collected pretest and posttest datasets adhere to the assumptions required for parametric analysis. According to the data, the experimental class yielded a test statistic of 0.638 with a sample size (N) of 36 students. Crucially, the resulting significance value (p-value) for this group fell below the 0.001 threshold. This extremely low probability value leads to the rejection of the null hypothesis, thereby confirming that the data distribution deviates significantly from a normal curve.

The control class demonstrated a comparable statistical pattern, exhibiting a test statistic of 0.823 across an identical sample size of 36 learners. Similar to the experimental group, this class generated a significance value (p-value) of less than 0.001, which officially designates the dataset as not normally distributed. Because both groups failed to meet the normality assumption, the selection of a non-parametric alternative, specifically the Mann-Whitney Test, becomes methodologically justified. While these distribution anomalies are fully accounted for by the analytical model, any subsequent interpretation regarding the pedagogical impact of Inquiry-Based Learning must remain cautious. Definitive causal claims about learning outcomes would require further validation through diagnostic misconception data, student interviews, or direct classroom observations to complement these quantitative trends.

Table 4. Results of Mann-Whitney Test on Students' Critical Thinking Skills

Ranks			
Group Name	**N**	**Mean Rank**	**Sum of Rank**
Experimental Class	36	47.33	1704.00
Control Class	36	25.67	924.00
Total	72	-	-

Test Statistic	
Statistic	**Score**
Mann-Whitney U	258.000
Wilcoxon W	924.000
Z	-4.393
Asymp. Sig. (2-tailed)	<0.001

The statistical breakdown of the non-parametric evaluation is documented thoroughly in Table 4 through the Ranks and Test Statistic values. Looking at the data pattern, the experimental class achieved a Mean Rank of 47.33, which accumulation resulted in a Sum of Ranks of 1704.00. This outcome contrasts visibly with the control class, which only managed a Mean Rank of 25.67 and a Sum of Ranks of 924.00. Such a substantial disparity between the two research groups points toward a notable difference in the post-intervention performance distributions. Consequently, these initial ranking metrics provide an early indication regarding the variance in critical thinking outcomes between the student cohorts.

Further inspection of the test statistics reveals a Mann-Whitney U value of 258.000 alongside a Wilcoxon W value of 924.000. The analysis also generated a Z-score of -4.393, indicating that the observed differences lie far from the statistical mean. More importantly, the asymptotic significance value (2-tailed) is recorded at less than 0.001, falling well below the standard alpha level of 0.05. This highly significant *p*-value leads to the rejection of the null hypothesis, confirming that the critical thinking skills of the two classes differ significantly. Methodologically, this statistical evidence clarifies that the performance gap between the groups is not a product of random chance.

Although the statistical metrics strongly favor the group exposed to Inquiry-Based Learning, interpreting these findings requires a balanced perspective. This numerical divergence suggests that the classroom environment might have influenced the students' capacity to analyze complex electrical circuit scenarios.

However, establishing a definitive causal link between the instructional model and intellectual growth remains challenging without supplementary qualitative evidence. Future investigations would benefit greatly from integrating student interview transcripts, direct classroom observation logs, or diagnostic misconception data to fully substantiate these claims. Therefore, the current statistical superiority should be viewed as a promising trend rather than absolute proof of direct pedagogical causation.

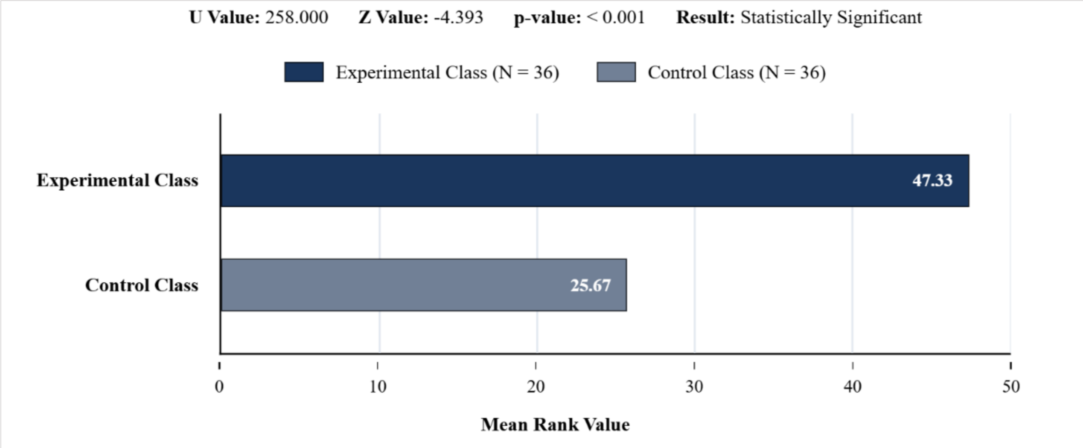

Figure 1. Comparing Critical Thinking Skill

The profound divergence between the two performance profiles in Figure 1 highlights a fundamental variance in cognitive adaptation between the student cohorts. Contrasting the superior mean rank of the class trained under Inquiry-Based Learning (IBL) against the stagnant baseline of the teacher-led control group indicates a clear stratification in problem-solving maturity. This distinct gap suggests that the systematic scaffolding within IBL significantly enhances conceptual resilience when students navigate complex engineering tasks, whereas conventional instruction restricts cognitive growth to surface-level memorization (Ennis, 2011). The measured performance differential is rooted in the model's capacity to transform passive learners into active investigators, a pedagogical shift that directly cultivates the higher-order analytical frameworks necessary for autonomous diagnostic reasoning (Dewey, 1998). Consequently, this stark comparative analysis implies that the inquiry intervention successfully stimulates specific investigative cognitive domains that typically remain entirely dormant under standard lecture-based regimes.

Students perform elementary clarification by identifying circuit anomalies and formulating investigative questions throughout the orientation and hypothesis generation phases. This structured problem-solving process moves learners toward what Dewey (1998) describes as "reflective thinking," where learning is stimulated by a state of doubt. The cognitive tension experienced when encountering unexpected electrical faults compels individuals to abandon passive absorption in favor of active mental processing. Encountering these technical challenges forces students to re-examine their prior assumptions regarding electrical current behavior. Therefore, the initial stage of IBL serves as a necessary catalyst for breaking routine cognitive habits and initiating deeper intellectual engagement.

Learners practice basic support and inference by validating hypotheses through physical measurements as they transition to the data collection phase. This active experimentation requires individuals to cross-reference theoretical circuit diagrams with actual multi-meter readouts and tangible component behaviors. Research by Nurwahid & Shodikin (2021) supports this, noting that inquiry-based environments strengthen the ability to form evidence-based arguments through hands-on manipulation. The empirical data points gathered by the students serve as concrete evidence that directly confirms or refutes their initial tentative explanations. This continuous feedback loop in the laboratory environment transforms abstract electrical laws into verifiable, logical realities.

Data analysis and conclusion drawing phases facilitate advanced clarification alongside strategic tactical reasoning. Students are required to justify their findings and reflect on their experimental consistency, a process Morris (2025) identifies as crucial for developing analytical depth. This stage forces learners to reconcile unexpected discrepancies, such as voltage drops or resistance variations, which often arise during practical vocational tasks. The statistical gap between groups confirms that the analytical skills required for electrical troubleshooting cannot be achieved through static instruction. Static lecturing fails to provide the cognitive friction necessary to build the diagnostic frameworks that vocational students need in real-world scenarios.

The IBL model effectively bridges the gap between theoretical abstraction and practical application by requiring students to manage uncertainty and analyze empirical data, thereby fulfilling the industry's demand for critical-thinking technicians. The significant difference in mean ranks illustrated in Figure 1 indicates that structured autonomy fosters a higher tier of diagnostic competence. However, interpreting these statistical trends as absolute proof of a direct causal relationship requires methodological prudence regarding internal validity. A comprehensive understanding of this intellectual growth would be strengthened by integrating diagnostic misconception data, student interview transcripts, or direct classroom observations. Relying on these diverse qualitative reference points ensures that the quantitative success observed in the experimental class is thoroughly validated.

2. The Effectiveness of Inquiry-Based Learning in Advancing Conceptual Understanding

The evaluation of conceptual understanding focused on the students' ability to internalize and apply fundamental electrical principles, specifically Ohm's Law. Preliminary diagnostic testing via the Shapiro-Wilk framework revealed an asymmetrical data distribution profile, particularly within the control cohort which generated a significance value below the 0.05 threshold. This departure from a normal Gaussian curve across the gathered datasets required a departure from standard parametric analytical methods. Non-parametric analysis using the Mann-Whitney Test was subsequently elected as the most robust statistical alternative to cross-examine the performance variances between the two pedagogical groups. The detailed empirical yields from this computational assessment are structured systematically within the subsequent data displays.

Table 5. Shapiro-Wilk Normality Test Results on Students' Conceptual Understanding Skills

Test of Shapiro-Wilk Normality				
Group Name	**Statistic**	**N**	**Significance (p-value)**	**Distribution Status**
Experimental Class	0.944	36	<0.068	Normally Distributed
Control Class	0.884	36	<0.001	Not Normally Distributed

Data organized within Table 5 reveals that the experimental cohort yielded a Shapiro-Wilk test statistic of 0.944 alongside a corresponding significance value (p-value) of 0.068. This critical probability value remains well above the conventional alpha threshold of 0.05, thereby leading to a failure to reject the null hypothesis. Retaining the null hypothesis confirms that the conceptual understanding scores within this inquiry-trained group adhere to a symmetric, normal distribution profile. Such statistical consistency indicates that the acquisition of core electrical concepts occurred uniformly across the various student aptitude layers within the experimental classroom. Consequently, this specific data subset fulfills the primary distributional benchmark typically required for standard parametric investigations.

The control cohort listed in Table 4 presented a completely divergent statistical trajectory, demonstrating a normality statistic of 0.884 across an identical sample size of 36 learners. Calculations for this teacher-led group produced an asymptotic significance value (p-value) of less than 0.001, falling substantially beneath the acceptable 0.05 confidence boundary. This extremely low probability value forces a decisive rejection of the null hypothesis, officially designating the control dataset as not normally distributed. Having one cohort break the symmetry of the regular distribution shape prevents the systematic application of standard parametric metrics across the entire comparative matrix. This unique combination of one normal and one non-normal distribution profile methodologically seals the decision to utilize the non-parametric Mann-Whitney framework for all subsequent cross-group evaluations.

Table 6. Results of Mann-Whitney Test on Students' Conceptual Understanding Skills

Ranks			
Group Name	**N**	**Mean Rank**	**Sum of Rank**
Experimental Class	36	47.19	1699.00
Control Class	36	25.81	929.00
Total	72	-	-
Test Statistic			
Statistic		**Score**	
Mann-Whitney U		263.000	

Wilcoxon W	929.000
Z	-4.338
Asymp. Sig. (2-tailed)	<0.001

Data compiled within the Ranks section of Table 5 outlines a distinct separation in conceptual attainment between the two instructional groups. The experimental class managed to achieve a high Mean Rank of 47.19, culminating in a total Sum of Ranks of 1699.00. This pattern contrasts sharply with the control cohort, which finished the evaluation period with a Mean Rank of 25.81 and a Sum of Ranks of 929.00. This visible gap between the ranking metrics implies that the student cohorts experienced highly unequal levels of academic growth. Consequently, these baseline distribution ranks offer a preliminary indication that the instructional environments yielded varying levels of understanding regarding fundamental electrical laws.

The Test Statistic portion of Table 6 delivers deeper mathematical confirmation regarding the observed divergence between the groups. Computation of the dataset produced a Mann-Whitney U value of 263.000 alongside a corresponding Wilcoxon W value of 929.000. The statistical model also generated a Z-score of -4.338, indicating that the performance gap sits multiple standard deviations away from the baseline mean. Crucially, the asymptotic significance value (2-tailed) is recorded at less than 0.001, falling well below the standard 0.05 alpha threshold. Rejection of the null hypothesis is therefore methodologically mandated, confirming that the post-intervention conceptual understanding of the two classes differs significantly.

The marked superiority of the inquiry-trained cohort suggests that the IBL framework may offer structural benefits for mastering complex vocational concepts like Ohm's Law. Passive lecturing setups often limit student engagement to rote memorization, whereas active inquiry prompts deeper cognitive integration of abstract engineering parameters. However, concluding that the instructional model is the absolute cause of this intellectual growth requires caution due to typical quasi-experimental design constraints. Fully verifying these mathematical trends as direct pedagogical outcomes would require backing from diagnostic misconception data, qualitative student interviews, or formal classroom observations. The quantitative findings should consequently be viewed as an indicator of a highly positive educational trend rather than definitive proof of a causal link.

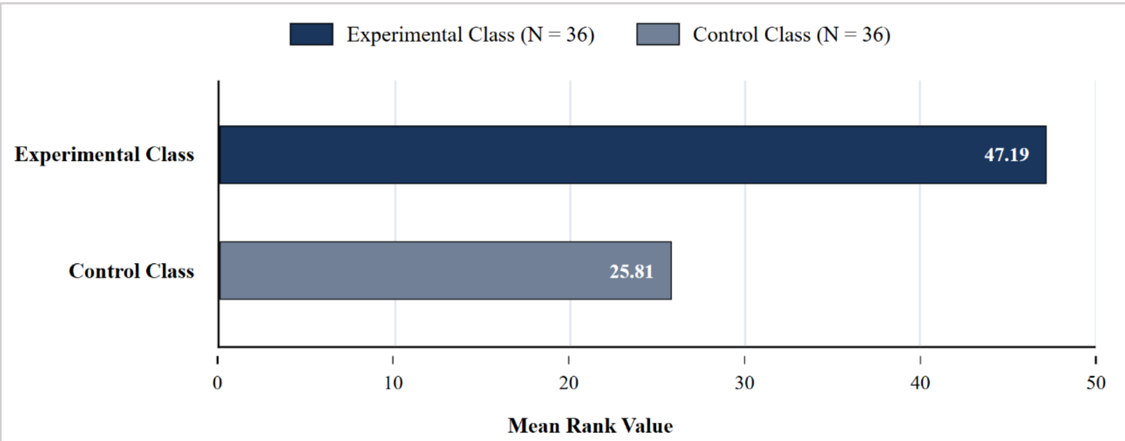

Figure 2. Comparing Conceptual Understanding Skill

The pronounced variance in mean ranks illustrated in Figure 2 isolates a fundamental divergence in how students systematically process functional mathematical relationships within electrical circuits. Contrasting the experimental group's high mean rank against the control cohort in Figure 2 demonstrates that traditional pedagogical structures fail to decouple rote memorization from genuine cognitive abstraction. This operational deficit is explained by Anderson & Krathwohl (2001), who emphasize that conceptual internalization requires learners to autonomously differentiate, organize, and execute structural knowledge schemas. Within the IBL framework, students are forced to actively map out the non-linear dependencies between voltage, current, and resistance rather than treating Ohm's Law as a static, isolated equation. Consequently, this continuous cognitive processing bridges the gap between passive declarative knowledge and the active mental frameworks needed to predict circuit behavior under varying operational loads.

The heightened efficacy of the inquiry model stems directly from the empirical friction encountered during the hands-on verification of circuit electrical parameters. Direct manipulation of variables allows students to experience how changing physical resistance values physically alters current readouts, transforming an abstract algebraic formula into a concrete physical law. This operational feedback loop aligns with the findings of Nurwahid & Shodikin (2021), who observed that contextualized experimental environments actively dismantle deep-rooted instructional misconceptions by providing unmediated physical proof. Confronting immediate data discrepancies in the laboratory forces vocational students to actively reconcile their theoretical assumptions with tangible multimeter measurements. The conventional control group, restricted to passive observation of teacher-led demonstrations, missed this active conceptual reconciliation and remained unable to independently deduce how circuit components interact under real-world technical stresses.

The absolute absence of negative rank regressions within the inquiry cohort implies that the cognitive framework developed through self-directed investigation remains highly resilient against conceptual decay. Technical stability in vocational electrical engineering depends heavily on shifting from simple fact-retrieval models to active, exploratory cognitive mapping. Forcing students to independently trace and isolate voltage drops across sequential components ensures that the resulting conceptual schemas become permanently integrated into long-term memory structures (Jumini, 2023). This level of deep conceptual mastery is operationally vital in power systems engineering because superficial, superficial understanding directly increases the risk of catastrophic diagnostic errors or occupational safety violations. Therefore, the structured autonomy within the inquiry model serves as a necessary mechanism for embedding the precise analytical habits required for industrial troubleshooting.

The emergence of eight tied ranks within the non-parametric dataset reveals that individual baseline differences still heavily mediate the final rate of conceptual internalization. Variations in prior mathematical literacy, distinct spatial-visual reasoning abilities, or uneven levels of intrinsic motivation created distinct learning velocities even within the highly supportive inquiry environment. This statistical finding demonstrates that no single instructional intervention can completely eliminate the heterogeneous learning curve inherent to an intact vocational classroom. This specific variance highlights a critical need to embed targeted, adaptive scaffolding mechanisms directly into the initial phase of the inquiry model to catch lagging students. Addressing these subtle instructional bottlenecks ensures that the cognitive benefits of active exploration are evenly distributed across all student competency profiles.

While the quantitative data in Figure 2 demonstrates a strong positive shift, drawing an uncompromised causal line between the IBL model and conceptual mastery requires substantial methodological caution. The quasi-experimental design utilized in this research cannot fully rule out the confounding influences of external variables, such as unmeasured peer interactions outside the laboratory or minor instructor fatigue across different hours. Fully verifying these statistical milestones as direct, exclusive products of the inquiry framework would require validation through diagnostic misconception inventories, student interview transcripts, or rigorous video-based classroom observations. Relying on these diverse, mixed-methods reference points prevents premature claims regarding instructional causality. Nevertheless, the current statistical evidence provides a strong empirical baseline that positions structured inquiry as a superior strategy for upgrading vocational instruction.

3. Theoretical Contributions and Practical Implementations in Vocational Education

This research extends the theoretical boundaries of vocational pedagogy by substantiating the transition from traditional, rote-based instruction toward a robust constructive-investigative framework. The findings provide a theoretical bridge between abstract cognitive theories and technical mastery, demonstrating that the internalization of electrical principles is not a passive byproduct of drills, but a deliberate result of active discovery. By integrating Ennis's (2011) critical thinking markers with Anderson & Krathwohl (2001) conceptual dimensions, this study offers a new synthesis of how higher-order reasoning can be operationalized within a specialized technical context. This theoretical shift suggests that in vocational education, critical thinking and technical proficiency are not separate competencies but are mutually reinforcing through the process of inquiry.

In the specific context of SMK Negeri 1 Sedayu, these results provide a transformative roadmap for instructional design and laboratory management. The study suggests that to cultivate industry-ready graduates, the school's Electrical Power Engineering department should move beyond a "procedural" laboratory culture toward an "investigative" environment. Practically, this involves a fundamental redesign of laboratory job sheets; instead of offering rigid, step-by-step instructions, the curriculum should present students with complex "circuit anomalies" or "problem-based scenarios." This approach forces students to formulate their own testing procedures and validate their findings through empirical evidence, effectively simulating the high-stakes troubleshooting environments they will encounter in the industrial sector.

The observed efficacy of this model offers a limited practical implication for vocational institutions operating under tight resource constraints or facing infrastructural disparities. Structured inquiry, through its systematic focus on logical formulation and manual variable tracking, potentially optimizes the utility of existing baseline laboratory equipment without requiring immediate investments in high-tech simulation hardware. Shifting the instructional emphasis from the mere speed of task completion to the depth of the investigative process allows schools to maintain high cognitive standards even with standard pedagogical tools. This systemic habituation to evidence-based decision-making and data-driven reasoning remains highly relevant to the disruptive demands of modern industry. Future research would explicitly need to evaluate how variations in physical laboratory infrastructure interact with the inquiry model before this operational efficiency can be generalized as an empirical conclusion.

Conclusion

The findings of this study provide clear indications that Inquiry-Based Learning (IBL) serves as an effective pedagogical framework for linking theoretical concepts with basic technical competencies in vocational education. Shifting students from passive instruction to active investigation within this specific setting appears to address the widespread challenge of static critical thinking and surface-level conceptual mastery. The statistical trends observed in the experimental group suggest that allowing students to manipulate variables directly helps develop a more structured understanding of fundamental principles like Ohm's Law. However, these localized outcomes cannot be broadly generalized across all vocational institutions due to the inherent sample limitations and the lack of full participant randomization characteristic of a quasi-experimental design. Future research should integrate diverse qualitative tracking methods across larger, randomized cohorts to verify these exploratory educational patterns more robustly.

This research underscores a strategic necessity for vocational high schools to adopt structured cognitive restructuring to meet the challenges of the modern industrial era. While previous literature often focused on general science, this study establishes the specific original value of IBL within the specialized context of Electrical Power Engineering. It proves that the model not only elevates higher-order thinking skills but also acts as a "cognitive leveler" that eliminates negative learning trends. These results offer a clear pathway for educational practitioners to produce an analytical workforce capable of navigating the unpredictable complexities of current industrial systems through the integration of inquiry-based methods.

References

Aarkrog, V. (2022). The significance of learning environment and decision-making for enrolment in and completion of VET: A Danish case. In S. Billett, B. E. Stalder, V. Aarkrog, S. Choy, S. Hodge, & A. H. Le (Eds.), *The standing of vocational education and the occupations it serves: Current concerns and strategies for enhancing that standing* (pp. 265–285). Springer International Publishing.

Adnyana, P. G. W., Suarsana, I. M., & Suharta, I. G. P. (2021). Multi-representation discourse model and math problem solving skills of high school students. *Journal of Learning Improvement and Lesson Study*, *1*(1), 40–48.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Complete ed.). Addison Wesley Longman.

Bartolomé, E. (2026). Adapting the 'study and research path' methodology in strength of materials to online teaching and resource-constrained scenarios. *International Journal of Mechanical Engineering Education*, *54*(1), 107–128.

Dewey, J. (1998). *The essential Dewey, volume 1: Pragmatism, education, democracy*. Indiana University Press.

Dietrich, H., & Evans, T. (2022). Traditional lectures versus active learning--a false dichotomy? ArXiv Preprint ArXiv:2206.12144.

Ennis, R. (2011). Critical Thinking. *Inquiry: Critical Thinking Across the Disciplines*, 26(1), 4–18. https://doi.org/10.5840/inquiryctnews20112613

Fitrianto, I., & Saif, A. (2024). The role of virtual reality in enhancing Experiential Learning: a comparative study of traditional and immersive learning environments. *International Journal of Post Axial: Futuristic Teaching and Learning,* 97–110.

Harleni, H., Ganefri, G., Yulastri, A., Giatman, M., Irfan, D., & Effendi, H. (2025). Unveiling The Impact of Inquiry-Based Learning: A Meta-Analysis of Student Learning Outcomes. *AL-ISHLAH: Jurnal Pendidikan*, 17(3). https://doi.org/10.35445/alishlah.v17i3.7061

Jumini, S. (2023). Efektivitas Model Pembelajaran Inkuiri Pada Materi Induksi Elektromagnetik Untuk Meningkatkan Pemahaman Konsep Siswa Sma. *Jurnal Luminous: Riset Ilmiah Pendidikan Fisika*, 4(2), 81–86.

Kovalchuk, V., Maslich, S. V, Tkachenko, N. M., Shevchuk, S. S., & Shchypska, T. P. (2022). Vocational education in the context of modern problems and challenges. *Journal of Curriculum and Teaching*, 8(11), 329–338.

Kumar, V., & Choudhary, S. (2024). Reimagining Scientific Literacy: A Framework for Future-Focused Science Education. https://doi.org/10.21203/rs.3.rs-4347536/v1

Li, Y., & Guo, M. (2021). Scientific Literacy in Communicating Science and Socio-Scientific Issues: Prospects and Challenges. Frontiers in Psychology, Volume 12-2021. https://doi.org/10.3389/fpsyg.2021.758000

Loyens, S. M. M., Van Meerten, J. E., Schaap, L., & Wijnia, L. (2023). Situating higher-order, critical, and critical-analytic thinking in problem-and project-based learning environments: A systematic review. Educational Psychology Review, 35(2), 39.

Morris, D. L. (2025). Rethinking science education practices: Shifting from investigation-centric to comprehensive inquiry-based instruction. Education Sciences, 15(1), 73.

Nurwahid, M., & Shodikin, A. (2021). Komparasi Model Pembelajaran Problem Based Learning dan Inquiry Based Learning Ditinjau dari Kemampuan Pemahaman Konsep dan Pemecahan Masalah Matematika Siswa dalam Pembelajaran Segiempat. Jurnal Cendekia: Jurnal Pendidikan Matematika, 5(3), 2218–2228.

Nuryanto, A., & Eryandi, K. Y. (2020). The 21st Century Ideal Skills for Vocational High Schools. Proceedings of the International Conference on Educational Research and Innovation (ICERI 2019), 142–147. https://doi.org/10.2991/assehr.k.200204.026

OECD. (2023). PISA 2022 results factsheets: Indonesia. OECD Publishing. Retrieved April 30, 2026, from https://gpseducation.oecd.org/CountryProfile?primaryCountry=IDN&topic=PI&treshold=10

Rachmad, Y. E. (2023). Tech Equity: Bridging Educational Gaps with Innovation. *Education Sciences Book Publishing Professional Book Basel.*

Rahimi, R. A., & Oh, G. S. (2024). Rethinking the role of educators in the 21st century: navigating globalization, technology, and pandemics. *Journal of Marketing Analytics*, 12(2), 182–197. https://doi.org/10.1057/s41270-024-00303-4

Rushton, E. A. C., Rawlings Smith, E., Steadman, S., & Towers, E. (2023). Understanding teacher identity in teachers' professional lives: A systematic review of the literature. *Review of Education*, 11(2), e3417.

Sabur, F., Kona, M., & Suprapto, Y. (2023). Inquiry-based learning on students' critical thinking skills at aviation vocational college. *Journal of Innovation in Educational and Cultural Research*, 4(4), 580–586.

Safkolam, R., Madahae, S., & Saleah, P. (2024). The effects of inquiry-based learning activities to understand the nature of science of science student teachers. *International Journal of Instruction*, 17(1), 479–496.

Salah, A. R. M. (2025). Ohm's Law: Electrical resistance and circuit behavior. *International Journal of Electrical Engineering Education*, 62(1), 45–59.

Sam, R. (2024). Systematic review of inquiry-based learning: Assessing impact and best practices in education. *F1000Research*, *13*, 1045–1068

.Sehole, L., Sekao, D., & Mokotjo, L. (2023). Mathematics conceptual errors in the learning of a linear function-a case of a Technical and Vocational Education and Training college in South Africa. *The Independent Journal of Teaching and Learning*, 18(1), 81–97.

Tadesse, E., Khalid, S., & Gao, C. (2025). Exploring higher vocational and training college students' learning motivation: a cross-national perspective. *Asia Pacific Journal of Education*, 1–17. https://doi.org/10.1080/02188791.2025.2497264

Warsi, Dr. L. Q., Sultana, R., & Muhammad Toheed Akhter. (2024). Impact of Instructional Coaching on Teaching-Learning Process. *Journal of Professional Research in Social Sciences*, 11(1), 309–343. https://doi.org/10.58932/MULA0032

Widiyanti, Y., Arum, J. W., Sukenti, E., Alfidayani, A., & Herawati, D. (2022). Impelemtation of Lesson Study Based STEM Learning to Stidents' Creativity and Concept Mastery Through Joint Project. Journal of Learning Improvement and Lesson Study, 2(1), 46–52. https://doi.org/10.24036/jlils.v2i1.17