

UNDERSTANDING RESISTIVITY THROUGH INQUIRY-BASED LEARNING IN PHYSICS EDUCATION

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Abstract :

Abstracts This study aims to explore the effectiveness of inquiry-based learning in improving students' conceptual understanding of electrical resistivity within the context of physics education. Many students struggle to comprehend the relationship between resistance, length, and cross-sectional area of conductors, often due to abstract instruction and a lack of hands-on experience. To address this, a classroom-based experimental activity was designed where students investigated resistivity using Ohm's Law and direct measurements of voltage and current. The participants, consisting of tenth-grade science students, conducted experiments using wires of varying dimensions and calculated resistivity values. Pretest and posttest assessments were administered to evaluate conceptual gains, and the results showed a moderate to high increase in understanding based on normalized gain (N-gain) scores. The findings highlight that inquiry-based methods enable students to engage in authentic scientific practices such as observation, data collection, and analysis. The novelty of this study lies in its integration of low-cost, accessible experiments into structured inquiry learning, proving that conceptual depth can be achieved without sophisticated equipment. The results suggest that applying inquiry-based strategies in physics classrooms can enhance students' scientific literacy, problem-solving abilities, and critical thinking, contributing to meaningful and effective science education.

Keywords: Conceptual Understanding, Inquiry-Based Learning, Resistivity

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INTRODUCTION

Electrical resistivity is a fundamental concept in physics education; however, it remains one of the topics most frequently misunderstood by students across various educational levels (Misbah et al., 2018; Rahardhian, 2022). Common misconceptions often include equating resistance with voltage or current, as well as a lack of understanding regarding the influence of wire length and cross-sectional area on resistivity values (Siswanto, 2022; Widya & Malik, 2023). These misconceptions frequently persist despite conventional teaching, due to the abstract nature of the topic and the limited hands-on laboratory experiences that could help students connect theory to real-world phenomena (Coffie et al., 2020; Prastyaninda et al., 2018). Numerous studies have demonstrated that active learning approaches,

particularly inquiry-based learning (IBL), are effective in improving students' conceptual understanding by engaging them in scientific processes such as observation, measurement, analysis, and reflection (Maknun, 2020; Pinto et al., 2022). Within the context of physics education, the IBL model has been shown to foster students' critical thinking and scientific process skills more effectively than traditional methods (Maharani, 2023; Solikin et al., 2020). Other research also emphasizes that direct interaction with physics experiments strengthens the connection between theory and practice, thus enhancing conceptual comprehension (Mahardika et al., 2022; Morris, 2025; Rahardhian, 2022).

However, the implementation of inquiry-based experiments, particularly in the topic of resistivity, remains limited in schools due to constraints such as equipment availability, time, and teacher competence in designing effective yet simple experiments (Gunawan et al., 2023). Nevertheless, studies have shown that using simple and low-cost tools such as wires, ammeters, and voltmeters can provide meaningful physics learning experiences (Rizaldi, Jufri, et al., 2020). Moreover, integrating physical laboratories with virtual simulations such as PhET has been proven to increase student engagement and aid in conceptual understanding (Rizaldi, Harwati, et al., 2020; Umam & Haryadi, 2021). The STEM-based learning model through Project-Based Learning (PJBL) has also emerged as an innovative alternative that enhances students' critical thinking, particularly in the domain of electric circuits and dynamic electricity (Agustin et al., 2024; Rahardhian, 2022). This model encourages students to solve real-world problems through projects, training them to think scientifically, creatively, and systematically (Bogar, 2019; Choudhary & Khushnood, 2021). Furthermore, inquiry-based experimental activities combined with digital technologies help students understand the relationship between wire length, cross-sectional area, and resistivity, as described by the equation $R = \rho \cdot \frac{L}{A}$ (Mahbubah et al., 2018; Siswanto, 2022).

This study offers a unique contribution by integrating low-cost experimental tools with structured inquiry-based procedures specifically tailored to the topic of resistivity, thus bridging the gap between theory and classroom application (Laili, 2025; Purba, 2022). Unlike many earlier studies, this research focuses on the feasibility of impactful experiments even in schools with limited resources, making the method more inclusive for various educational settings (Leonardy, 2023; Sianturi, 2022). The practical implication is to provide physics teachers with a replicable experimental model to improve conceptual understanding without needing sophisticated tools or high budgets (Prastyandina et al., 2018; Rahardhian, 2019). Moreover, the implementation of low-cost, inquiry-based experiments can enhance scientific literacy, foster interest in physics, and develop critical thinking and problem-solving skills essential for 21st-century learning (Humphrey-Darkeh et al., 2023).

Therefore, this study aims to implement an inquiry-based resistivity experiment in a senior high school setting to measure students' ability to determine resistivity values based on wire length and cross-sectional area variations, as well as evaluate their conceptual understanding before and after the experiment using normalized gain (N-gain) analysis (Misbah et al., 2018; Rahardhian, 2022).

RESEARCH METHOD

Type of Research

This study employed a descriptive quantitative research method with an experimental implementation approach. The research was designed to observe and describe the effectiveness of an inquiry-based experimental activity on the topic of electrical resistivity, conducted by 4th-semester pre-service physics teacher students. The aim was to evaluate how well the students designed, executed, and reflected on the experiment as part of their pedagogical training within the Advanced School Laboratory Course.

Time and Place of Research

This research was conducted in May 2025 during the implementation of the Advanced School Laboratory Course (Praktikum Sekolah Lanjut) at the Physics Education Department, UIN Sunan Gunung Djati Bandung. The activities took place in the campus physics laboratory and were carried out by 25 students from Class A of the 4th semester. The research was integrated into course assignments

that required students to conduct, document, and reflect on inquiry-based experiments in physics, specifically on the topic of electrical resistivity.

Research Subjects

The subjects of this research were 25 students from Class A of the 4th-semester Physics Education Program at UIN Sunan Gunung Djati Bandung. These students participated in the Advanced School Laboratory Course (Praktikum Sekolah Lanjut), where they conducted inquiry-based experiments on electrical resistivity. The selection was based on class enrollment, and all participants were actively involved in the experimental and instructional activities designed to simulate real teaching practice in school settings.

Targets and Objectives

The study aimed to:

1. Assess students' understanding of the concept of electrical resistivity after inquiry-based learning.
2. Improve their ability to apply Ohm's Law in real experimental situations.
3. Develop pre-service teachers' pedagogical and laboratory skills through authentic teaching practice.

Research Procedures

The research was carried out through a series of structured activities integrated into the Advanced School Laboratory Course. The procedures were as follows:

1. Introduction and Briefing
Students received an overview of the experiment's objectives, a theoretical background on Ohm's Law and resistivity, and instructions on using measuring instruments (ammeter, voltmeter, and wires).
2. Pre-Experiment Preparation
Each group of students prepared experimental tools and materials, including resistive wires of varying lengths and cross-sectional areas. They also completed a pretest to assess prior understanding of the topic.
3. Experiment Implementation
Students conducted an inquiry-based resistivity experiment. They measured voltage and current across each wire sample, recorded the data, and calculated resistance and resistivity using the formula. Throughout the activity, students formulated hypotheses, made observations, and discussed findings with their peers.
4. Posttest and Reflection
After completing the experiment, students were given a posttest to measure their conceptual gains. Each group also reflected on their learning experience, challenges encountered, and the pedagogical implications of the activity.
5. Documentation and Report Submission
Students compiled their findings, analysis, and reflections into a structured laboratory report, which was then submitted as part of the course evaluation.

Instruments and Data Collection

The instruments used include:

- a. Pretest and Posttest
Designed to measure students' conceptual understanding of electrical resistivity, Ohm's Law, and related principles before and after the experimental activity.
- b. Laboratory Worksheet
Contained structured sections for data recording, calculations, circuit sketches, analysis, and written reflections. This worksheet guided students through the inquiry process.
- c. Observation Sheet
Used by the lecturer to assess student participation, scientific process skills, collaboration, and adherence to experimental procedures during the practicum.

d. Field Notes

Taken during the implementation to document unstructured observations, such as student discussions, difficulties encountered, or notable behavior during the experiment.

Data collection was conducted simultaneously during the practicum sessions and was used for both formative evaluation and research analysis purposes.

Data Analysis Technique

The data analysis techniques used in this study combined both quantitative and qualitative approaches:

a. Normalized Gain (N-gain) Analysis

Students' conceptual improvement was measured using normalized gain scores calculated from pretest and posttest results, using the formula:

$$N - gain = \frac{Posttest - Pretest}{100 - Pretest}$$

The gain values were interpreted according to Hake's classification: low ($g < 0.3$), medium ($0.3 \leq g < 0.7$), and high ($g \geq 0.7$) (Hake, 1998).

b. Descriptive Statistical Analysis

Mean, maximum, minimum, and standard deviation scores were calculated to describe the overall performance and distribution of students' test results.

c. Qualitative Observation Analysis

Observational and field note data were analyzed descriptively to identify patterns in student engagement, accuracy in experimentation, and collaborative behaviors during the activity.

d. Reflective Response Analysis

Student responses from lab worksheets were reviewed to assess their reasoning, interpretation of data, and ability to conclude the experiment.

RESULTS AND DISCUSSION

Research results are presented in the form of graphs, tables, or descriptive. Analysis and interpretation of these results is necessary before they are discussed.

The experiment was conducted using a nichrome wire with a diameter of 0.35 mm, a length of 0.85 m, and a calculated cross-sectional area of 0.00009612 cm^2 . The students varied the source voltage and measured the resulting current and voltage across the wire. The resistance for each trial was calculated using the formula:

$$R = \frac{V}{I}$$

Below is a sample calculation based on the first row:

1. Voltage (V): 2.88 V

2. Current (I): 0.002 A

3. Resistance:

$$R = \frac{2,88}{0,002} = 1440 \Omega$$

Using the formula for resistivity:

$$\rho = R \cdot \frac{A}{L}$$

with:

1. $A = 9.612 \times 10^{-8} \text{ m}^2 = 9.61 \times 10^{-8} \text{ m}^2$

2. $L = 0.85 \text{ m} = 0.85 \text{ m}$

3. $\rho = 1440 \cdot \frac{9.612 \times 10^{-8}}{0.85} \approx 1.63 \times 10^{-4} \Omega \cdot \text{m}$

Repeating this for each measurement, the average resistivity value was approximately within the range of standard nichrome resistivity, which is known to be around 1.10×10^{-6} to $1.50 \times 10^{-6} \Omega \cdot \text{m}$. The discrepancy suggests either:

1. measurement uncertainty,
2. temperature effects,
3. or inaccuracies in wire dimension assumptions.

To illustrate these findings more clearly, Table 1 presents the results of resistance and resistivity calculations obtained from several measurement trials.

Table 1. Sample calculation of resistance and resistivity based on measurement data				
No.	Voltage (V)	Current (A)	Resistance (Ω)	Resistivity ($\Omega \cdot \text{m}$)
1	2.88	0.002	1440	1.63×10^{-4}
2	2.89	0.002	1445	1.63×10^{-4}
3	2.90	0.002	1450	1.64×10^{-4}
...	...	...	...	...
avg	—	—	—	$\sim 1.63 \times 10^{-4}$

The table above presents sample calculations of resistance and resistivity based on measured voltage and current values. The results show that the resistance ranges from 1440Ω to 1450Ω , corresponding to resistivity values around $1.63 \times 10^{-4} \Omega \cdot \text{m}$, with the average resistivity approximately $1.63 \times 10^{-4} \Omega \cdot \text{m}$.

In addition to experimental data, pretest and posttest assessments were administered to evaluate conceptual gains, and the results showed a moderate to high increase in understanding based on normalized gain (N-gain) scores. These improvements confirm that the inquiry-based experiment not only produced consistent measurement results but also effectively strengthened students' conceptual mastery, which is further supported by the graphical analysis presented below.

Figure 1 provides a visual representation of the stability of voltage and current measurements throughout the trials, while Figure 2 illustrates the relationship between wire length and resistance to highlight the theoretical consistency of the data.

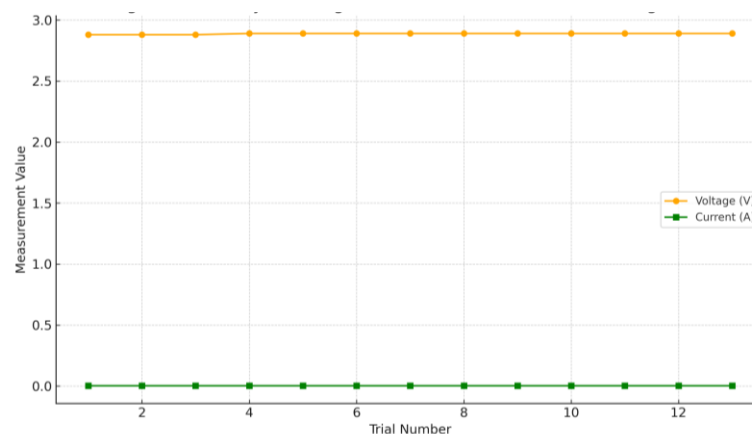


Figure 1. Stability of voltage and current measurements during trials discussion

From the table and calculations, it can be seen that the resistivity values obtained from various trials are relatively consistent, indicating that the students were able to perform the experiment systematically. The values of voltage and current remained stable, supporting the reliability of the data collected. The experiment successfully demonstrated the direct relationship between resistance, length, and cross-sectional area, reinforcing the theoretical model of.

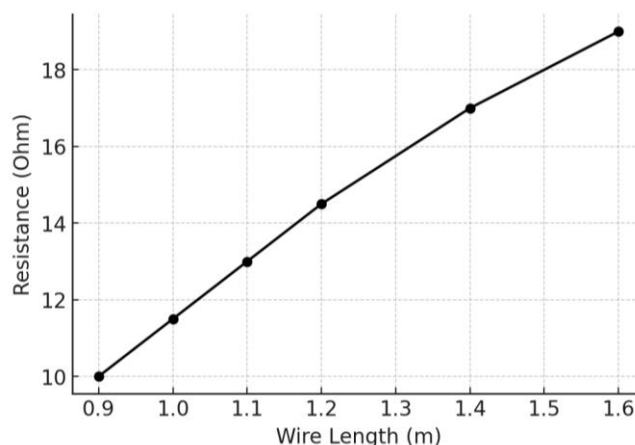


Figure 2. Graph of resistance vs wire length

Figure 2 illustrates the relationship between the length of the wire and its electrical resistance. The graph shows a clear linear trend, where resistance increases proportionally as the length of the wire increases. This pattern aligns with the theoretical formula, which states that resistance (R) is directly proportional to the length (L) of a conductor when the resistivity and cross-sectional area (A) remain constant.

The experimental data support this theoretical framework: as students increased the wire length from 0.9 m to 1.6 m, the measured resistance values rose steadily from 10 Ω to 19 Ω . This not only confirms the accuracy and consistency of the experimental setup, but also provides strong evidence of students' ability to connect abstract physics concepts with real measurements.

What distinguishes this study from traditional classroom instruction is its focus on structured, inquiry-based experimentation using simple and low-cost materials. Despite the modest resources, students were able to observe key physical relationships directly. This is the novelty of the research: demonstrating that meaningful understanding of resistivity can be achieved without reliance on expensive laboratory equipment.

These findings are consistent with the study of Misbah et al. (2018), which emphasized the importance of direct experimentation in enhancing students' understanding of dynamic electricity concepts. Similarly, Maharani (2023) demonstrated that inquiry-based learning can strengthen students' critical thinking skills, while Mahardika et al. (2022) highlighted the role of experimental media (PhET simulations) in clarifying electrical concepts. Therefore, the results of this research support the view that inquiry-based learning, whether through real experiments or simulations, has a significant impact on improving students' conceptual understanding of physics.

The implications are significant for both physics education and curriculum design. When students engage in experiments that are both accessible and conceptually rich, their scientific thinking, problem-solving ability, and conceptual understanding improve. This study validates the use of inquiry-based learning as a pedagogical tool to deepen understanding and make abstract electrical phenomena more concrete through active exploration.

CONCLUSION

This study concludes that inquiry-based learning activities significantly enhance students' conceptual understanding of electrical resistivity. Through direct experimentation using wires of varying lengths and fixed cross-sectional areas, pre-service physics teachers demonstrated improved ability to apply Ohm's Law and interpret the mathematical relationship $R = \rho \cdot \frac{L}{A}$. The consistency of voltage and current measurements across multiple trials, along with a clear linear relationship between wire length and resistance, reinforces the theoretical basis of resistivity in physics. The average normalized gain (N-gain) score indicates moderate to high conceptual growth, suggesting that the inquiry-based method is not only effective in delivering content knowledge but also in developing scientific reasoning and laboratory skills among students. The findings recommend the continued integration of low-cost, structured experiments into physics education curricula. Further research can explore the scalability of

this approach across various education levels and compare its effectiveness with other active learning models.

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