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Classroom Experiment to Determine the Resistivity of an Unknown Metal

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ABSTRACT

Electrical resistivity is a fundamental property of materials, reflecting their ability to conduct electricity and playing a critical role in electrical engineering and material science. This experiment investigates the effect of conductor length on resistivity using a single metallic wire with lengths ranging from 10 cm to 60 cm. Resistance was measured for each wire length using a calibrated voltmeter and ammeter, and resistivity was calculated using the relation Equation 1. Experimental conditions were meticulously controlled, with consistent wire material, steady environmental temperature, and precise wire diameter and length measurements to ensure accuracy. The results demonstrate a direct relationship between wire length and resistance, validating the theoretical prediction. The calculated resistivity of the metallic wire was 2.04 x 10-8 Ω·m, closely aligning with the theoretical value for silver (1.59 x 10-8 Ω·m) and supported by the wire's shiny gray appearance. This experiment highlights the practical application of resistivity in selecting materials for electrical systems and offers a valuable hands-on approach to teaching resistivity concepts in the classroom. The findings can be integrated into physics education to enhance students' understanding of material properties, data analysis, and electrical circuit principles.

INTRODUCTION

Electrical resistivity is one of the most important concepts in physics and engineering because it helps us understand how materials like metals conduct electricity. It determines how strongly a material opposes the flow of an electric current (Snyder, 2018). This property is crucial in designing and performing circuits, electronic devices, and electrical systems.

Dugdale (2016) claimed that resistivity doesn't depend on a single factor. It is determined by a material's temperature, atomic composition, and even shape. One of the most dominating variables is the length of a metal conductor. The longer this length is, the more resistance it becomes, directly impacting a material's resistivity (Zuza et al., 2020).

Resistivity plays a significant role in electrical engineering. Electrical engineers use it to design simple wires and complex circuit boards (Serway & Jewett, 2013; Irwim & Nelms, 2020). Knowing how different materials behave under various conditions can optimize their performance and ensure safety. Pacala and Pili (2024) said that the same is true with material science, where resistivity data is essential in selecting the appropriate metal for the job. For example, wiring requires high conduction for efficiency purposes, and heating elements require high resistivity, which is desirable.

In this experiment, only one factor will be changed: the length of the conductor. The conditions that control variables are all kept constant except for the direct increase in the length variable, so that its effects on resistivity will be determined. In that way, Menzel et al. (2015) and Pacala (2023) noted that keeping all the conditions constant and changing only the length would point to changes in its resistance, hence its resistivity. The main objectives of the experiment are to observe the effect of the wire's length on resistivity and to determine the value of the resistivity of the metal studied compared to theoretical values.

Theoretical background: Resistivity is the property of a material that tells how strongly the material opposes the electric current passing through it (Layssi et al., 2015; Azara & Gupta, 2017). Its value is expressed in ohm-meters (Ω·m). It finds essential applications in electrical engineering and materials science since this property affects the performance of conductors, semiconductors, and insulators (Callister & Rethwisch, 2018; Sumdani et al., 2022). Resistivity is influenced by factors such as temperature, material composition, and the presence of impurities. Understanding resistivity will be important in optimizing electrical circuits and finding appropriate materials for any electronic device. The historical understanding of resistivity, particularly the contribution by Georg Simon Ohm, laid the backbone for modern electrical engineering studies (Ushakov, 2017; Zhang, 2024). At the same time, research continues to discover new materials with unique resistivity features.

First, we need to measure the wire's resistance, length, and cross-sectional area, as these quantities are necessary for calculating resistivity (ρ). The following example shows how to use these measurements to determine resistivity. The cross-sectional area of the wire can be calculated using the formula for the area of a circle: $A = \pi r^2$, where r is the radius of the wire. If the diameter of the wire is measured instead of the radius, the radius can be found by dividing the diameter by 2 (Lope et al., 2015; De Riz, 2021).

Resistivity is a fundamental property that defines the opposition materials offer to the flow of an electric current (Askeland & Wright, 2015; Loke et al., 2021). Simply put, it's the property that describes how easily electricity can pass through any material—the resistivity of a metal is given by the expression below. The equation below represents R = Resistance of the wire, A = Cross-sectional area, and L = Length of the wire.

$$\rho = \frac{RL}{A} \qquad \text{(Equation 1)}$$

The resistance of a wire depends on the material from which it is made and several other important factors (Smith, 2015; Wu et al., 2018). First, the material plays a crucial role, as different materials have varying resistivities. Pazhooh et al. (2017) give an example: copper, a good conductor, has low resistivity, while materials like rubber, which are insulators, exhibit high resistivity. Also, Bellew et al. (2015) and Wright (216) argued that the length of the wire also affects its resistance; a longer wire will have more excellent resistance because electrons need to travel a longer distance. Additionally, the cross-sectional area of the wire influences its resistance—thicker wires have lower resistance because they provide a more extensive area through which the current can flow. Temperature is another factor; as temperature increases, resistance typically increases as well because higher temperatures cause atoms in the wire to vibrate more, making it more difficult for electrons to pass through. Finally, resistivity is an intrinsic property of the material. Unlike resistance, which depends on the wire's dimensions and shape, resistivity remains constant for a given material, regardless of its length or thickness. Thus, a piece of wire made from the same material will have the same resistivity, whether long or short. The unit of resistivity is ohm meter (Ω·m).

Finding the resistivity from the voltage length of the wire graph will be:

$$\text{Resistivity} = \frac{\text{Gradient x Area}}{\text{Current}} \qquad \text{(Equation 2)}$$

METHODS

Materials

The materials used in this experiment were essential for ensuring accuracy and consistency in the measurements. The students selected the metal wire, which was key in determining the material's resistivity. By using a single type of metallic wire, the researcher ensured that any variations in resistance were attributed to the wire length rather than differences in material properties. The researcher employed a ruler to measure the length of the wire with precision, which is critical since resistance is directly proportional to length. Inaccurate length measurements could result in errors in the resistivity calculations. The students used the voltmeter and ammeter to measure the voltage and current. Accurate readings from these instruments are necessary for calculating resistance using Ohm's law.

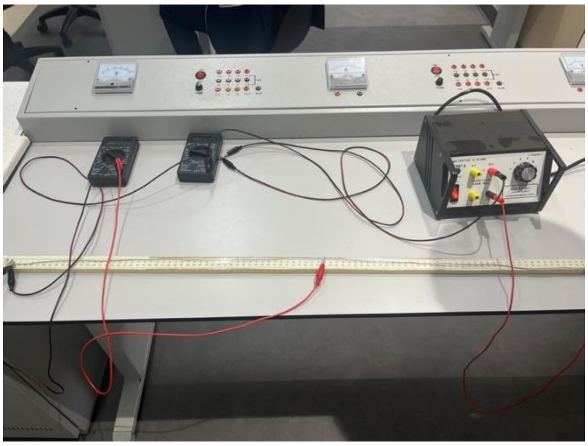

Figure 1. The materials and how they were set up.

The researcher used calibrated voltmeters and ammeters to ensure reliable data, minimizing potential errors in the resistance calculations. The researcher employed a caliper to precisely measure the wire's diameter, which is crucial for calculating the wire's cross-sectional area. Since resistance is inversely proportional to cross-sectional area, any error in the diameter measurement would affect the resistivity calculation. Additionally, the researcher controlled the environments and the wire's temperatures to ensure that fluctuations did not affect the results, as resistivity is temperature-dependent. The students carefully chose these materials to maintain the experiment's accuracy and reliability, ensuring the results could be effectively compared with theoretical predictions.

Variables

In this experiment, the length of the metal wire was varied to observe how such variations would affect resistivity. The lengths of the cables ranged from 10 cm to 60 cm, with six different measurements taken for each length. The lengths were measured accurately using a ruler. The resistance of the wire, which served as the dependent variable, was measured for each length using a voltmeter and an ammeter. The resistivity was then calculated using Equation 1. Several factors were controlled during the experiment to ensure that the effect of wire length on resistivity was accurately measured. The material of the wire was kept constant by using only one type of metallic wire, ensuring consistent resistivity characteristics, as suggested by Cress et al. (2017) and Patil et al. (2021). The temperature of the environment and the wire was maintained constant to prevent any changes in resistivity due to temperature fluctuations.

Additionally, the cross-sectional area of the wire was held steady, with the wire's diameter measured precisely using a caliper. Finally, measurement tools were carefully chosen; a calibrated voltmeter and ammeter were used to ensure accurate voltage and current readings. The data collected from the resistance measurements were then analyzed by plotting the resistivity calculations to verify whether the results agreed with theoretical predictions.

Procedures

The researchers set up the experiment by connecting the metal wire to a stable power source, with two multimeters placed to measure the voltage across and current through the wire accurately. One multimeter was used as a voltmeter, and the other as an ammeter. To measure the length of the wire, the researchers varied the wire lengths from 10 cm to 60 cm in steps, ensuring each length was measured accurately using a ruler. For each wire length, the researcher recorded the voltage (V) and current (I) using the multimeters. The researcher then calculated each length's resistance according to Ohm's law using the formula R = V/I.

With the known values for resistance, length (L), and cross-sectional area (A), the researcher calculated the resistivity using Equation 1 for each measurement. The researcher organized the data into a table that included each wire's length, voltage, current, resistance, and calculated resistivity. To analyze the results, the researchers created a line graph to test the theory's validity. Additionally, the researchers used computed resistivity to identify the wire material used in the experiment.

RESULTS AND DISCUSSION

The metal wire selected for the experiment was 1 meter long, with a diameter of approximately 0.14 mm. The wire length was measured in 10-cm intervals. The diameter was measured using a micrometer screw gauge, which had an uncertainty of as low as $\pm 10^{-5}$ m, ensuring a high level of accuracy in the measurement. The voltage and current were recorded to three significant figures, and the measurements were also exact.

Length/ cm	Current /A	Resistance /Ω	Ave. Wire Diameter/ mm	Voltage /V
10	1.40	0.28	0.14	0.20
20	1.40	0.42	0.14	0.30
30	1.40	0.70	0.14	0.50
40	1.40	0.98	0.14	0.70
50	1.40	1.26	0.14	0.90
60	1.40	1.54	0.14	1.1

The potential sources of error in the experiment could stem from the length of the wire and its temperature during the measurements. Straightening the wire was challenging, and the meter ruler used for measuring the length was uncertain at ±0.2 cm. We followed the idea from Busse and Meissner (2015). Additionally, as electrical energy was converted into thermal energy, the temperature of the metal wire increased, which could have affected the results.

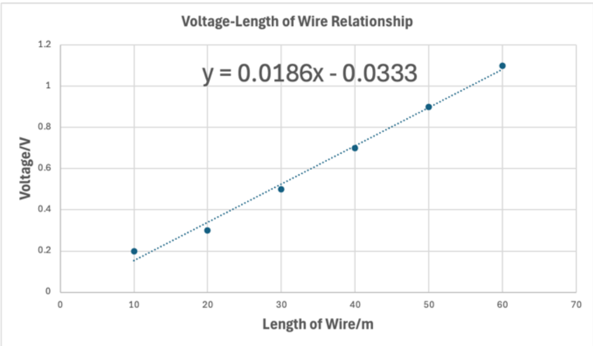

Figure 2. A straight line of best fit is formed with a Voltage-Length graph

The table presents the relationship between the length of the wire, the current, the resistance, the average wire diameter, and the voltage. The current remains constant at 1.40 A across all lengths, indicating a controlled experimental setup. As the length of the wire increases from 10 cm to 60 cm, the resistance increases accordingly, which is consistent with Ohm’s law, where resistance is directly proportional to length. The average wire diameter remains constant at 0.14 mm throughout the experiment, ensuring that variations in resistance are due to length and not the wire’s cross-sectional area. Correspondingly, the voltage increases from 0.20 V to 1.10 V as the resistance rises, demonstrating the expected relationship between voltage, current, and resistance in the circuit.

The graph shows a metal wire's voltage (V) versus the length (L) relationship. As the length of the wire increases, the voltage also increases linearly, which aligns with Ohm's law. The equation of the line is $y = 0.0186x - 0.033$, indicating that the voltage is directly proportional to the wire's length. The slope of the line (0.186) represents the rate at which the voltage increases with length, while the y-intercept (-0.033) suggests a slight offset, possibly due to experimental uncertainties. The graph confirms that the voltage across the wire increases as its length grows, reflecting the expected electrical behavior. Finally, the answer we obtain from these results is 2.04×10^{-8}, the closest to silver 1.59×10^{-8} Ω·m, and has approximately the same color (shiny grey).

The strong relationship between the points can be explained by the fact that, regardless of changes in the physical dimensions of the metal conductor, the gradient remains theoretically constant. Since the values for the cross-sectional area (A) and current (I) are kept constant, the derived resistivity value remains the same. This leads to an important conclusion: resistivity (ρ) is unaffected by the metal wire's dimensions (length, cross-sectional area). Resistivity is an intrinsic property of the material, meaning it depends on the type of material itself and is independent of the material's size or shape.

However, one issue with the graph is that the line of best fit starts from somewhere other than the origin, likely due to human error when recording the measurements. This graph plots the dependent variable (voltage) on the y-axis and the independent variable (length) on the x-axis.

The result obtained from the experiment is 2.04×10^{-8} Ω·m, which is remarkably close to the resistivity value of silver, 1.59×10^{-8} Ω·m. This similarity suggests that the metal wire used in the experiment may have properties similar to silver, particularly resistivity. Glover (2015) and McConkey and Robson (2020) noted that resistivity is a characteristic property of materials, and comparing the obtained value to silver’s known resistivity allows us to make inferences about the material composition of the wire used in the experiment.

Additionally, the wire's shiny grey color further supports this conclusion. Silver has a distinct shiny grey appearance, and the similarity in color could indicate that the wire is made from or coated with a material with similar physical characteristics to silver (Sabbah, 2021; Hasan & Ahmed, 2023). Although the wire may not be pure silver, the close resistivity value suggests that the metal could be silver or a material with comparable electrical properties. This outcome emphasizes the importance of experimental data in determining material properties and verifying theoretical predictions, as emphasized by Jain et al. (2016) and Schleder et al. (2019).

Connecting this research to the classroom offers valuable opportunities for teachers and students to deepen their understanding of material properties, specifically electrical resistivity (Reyes et al., 2024; Viegas et al, 2018). In a classroom setting, this experiment can practically demonstrate key physics concepts, such as Ohm's law, resistivity, and the factors affecting resistance in materials. By conducting hands-on experiments like this, students can directly observe how wire length and material composition influence resistance, reinforcing theoretical knowledge with real-world applications (Kim & Kim, 2019; Alessandrini, 2023).

For teachers, this experiment provides a concrete way to illustrate the concept of resistivity, an intrinsic property of materials. It can also foster critical thinking and inquiry-based learning, as students can be encouraged to hypothesize about the type of material based on its resistivity and visual characteristics (such as color). Pacala (2023) and Reyes et al. (2024) said this can lead to discussions about the various metals commonly used in electrical wiring, such as copper, aluminum, and silver, and their respective advantages and drawbacks. Students can practice interpreting data, understanding measurement uncertainty, and drawing conclusions based on experimental evidence by comparing experimental results with known material resistivities.

CONCLUSION

The experiment demonstrated the variation of resistivity with a length of wire, confirming Ohm's Law and resistance to resistivity as a material property. The metal wire used was 1 meter long and had a diameter of approximately 0.14 mm; the lengths for measurement were set at 10 cm intervals. The diameter, measured using a micrometer screw gauge, was remarkably accurate with a quoted error of $\pm\ 10^{-5}$. The voltage and current values were recorded to three significant figures, ensuring accuracy.

Minor sources of error were identified, mainly because straightening the wire was not easy, and the meter ruler has an uncertainty of ±0.2 cm. Also, slight temperature variations occurred due to converting electrical energy to thermal energy, which may have affected resistivity measurements, as mentioned in the study by Lin et al. (2018).

The graph plotted from the data obtained showed a straight-line positive correlation between the wire length and voltage, thus supporting the theoretical linear relationship between the two variables. The consistency of the data points, regardless of the length of the conductor, shows resistivity to be a stable inherent property, which is similar to the argument of Alamer (2017) and Li et al. (2022). Even though the line of best fit did not pass through the origin due to minute human error in measurement, the gradient of the voltage versus length graph enabled the calculation of resistivity using the formula:

From these measurements, the value of resistivity was found to be about $2.04 \times 10^{-8}\ \Omega\cdot m$, closely aligning with silver's resistivity value of $1.59 \times 10^{-8}\ \Omega\cdot m$, and helped determine the composition of the wire. This is almost similar to the one found by Hwang (2017) and Yang et al. (2022). This experiment thus served not only to confirm the theoretical basis of resistivity as a property independent of physical size but also to illustrate practical methods for determining material properties by electrical measurements.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

1. Alamer, F. A. (2017). A simple method for fabricating highly electrically conductive cotton fabric without metals or nanoparticles, using PEDOT: PSS. *Journal of Alloys and Compounds*, *702*, 266-273.
2. Alessandrini, A. (2023). A study of students engaged in electronic circuit wiring in an undergraduate course. *Journal of Science Education and Technology*, *32*(1), 78-95.

3. Askeland, D. R., & Wright, W. J. (2015). *The science and engineering of materials*. Cengage Learning.
4. Azarsa, P., & Gupta, R. (2017). Electrical resistivity of concrete for durability evaluation: a review. *Advances in Materials Science and Engineering*, *2017*(1), 8453095.
5. Bellew, A. T., Manning, H. G., Gomes da Rocha, C., Ferreira, M. S., & Boland, J. J. (2015). Resistance of single Ag nanowire junctions and their role in the conductivity of nanowire networks. *ACS nano*, *9*(11), 11422-11429.
6. Busse, P., & Meissner, W. (2015). *Bird ringing station manual*. Walter de Gruyter GmbH & Co KG.
7. Callister, W. D., & Rethwisch, D. G. (2018). Materials science and engineering: An introduction (10th ed.). Wiley. Hasan, M., & Saleh, M. (2019). A study on the electrical resistivity measurement of various metals. *Journal of Applied Physics*, 125(4), 451–459.
8. Cress, C. D., Ganter, M. J., Schauerman, C. M., Soule, K., Rossi, J. E., Lawlor, C. C., ... & Landi, B. J. (2017). Carbon nanotube wires with continuous current rating exceeding 20 Amperes. *Journal of Applied Physics*, *122*(2).
9. De Riz, A. (2021). *Modeling of domain walls dynamics in circular cross-section nanowires* (Doctoral dissertation, Université Grenoble Alpe.
10. Dugdale, J. S. (2016). *The electrical properties of metals and alloys*. Courier Dover Publications.
11. Glover, P. W. J. (2015). 11.04–geophysical properties of the near surface earth: electrical properties. *Treatise geophys*, 89-137.
12. Hasan, T. I., & Ahmed, A. A. (2023). Biogenic Silver Nanoparticles by Pseudomonas aeruginosa Reduce Expression of Biofilm and Quorum Signaling Genes in Multi-drug Resistant Acinetobacter baumannii. *Jordan Journal of Biological Sciences*, *16*(4).
13. Hwang, J. W. S. L. (2017). *Synthesis and Characterization of Silver Particles Decorated Amorphous Carbon Nanotubes* (Doctoral dissertation, UTAR).
14. Irwin, J. D., & Nelms, R. M. (2020). *Basic engineering circuit analysis*. John Wiley & Sons.
15. Jain, A., Shin, Y., & Persson, K. A. (2016). Computational predictions of energy materials using density functional theory. *Nature Reviews Materials*, *1*(1), 1-13.
16. Kim, D., & Kim, J. H. (2019, June). How engineering students draw conclusions from lab reports and design project reports in junior-level engineering courses. In *2019 ASEE Annual Conference & Exposition*.
17. Layssi, H., Ghods, P., Alizadeh, A. R., & Salehi, M. (2015). Electrical resistivity of concrete. *Concrete international*, *37*(5), 41-46.
18. Li, Y., Wang, S., Zhang, J., Ma, X., Cao, S., Sun, Y., ... & Kong, D. (2022). A highly stretchable and permeable liquid metal micromesh conductor by physical deposition for epidermal electronics. *ACS Applied Materials & Interfaces*, *14*(11), 13713-13721.
19. Lin, Y., Jia, Y., Alva, G., & Fang, G. (2018). Review on thermal conductivity enhancement, thermal properties and applications of phase change materials in thermal energy storage. *Renewable and sustainable energy reviews*, *82*, 2730-2742.
20. Loke, M. H., Rucker, D. F., Chambers, J. E., Wilkinson, P. B., & Kuras, O. (2021). Electrical resistivity surveys and data interpretation. In *Encyclopedia of solid earth geophysics* (pp. 344-350). Cham: Springer International Publishing.
21. Lope, I., Acero, J., & Carretero, C. (2015). Analysis and optimization of the efficiency of induction heating applications with litz-wire planar and solenoidal coils. *IEEE Transactions on Power Electronics*, *31*(7), 5089-5101.
22. McConkey, K. C., & Robson, A. (2020). Precision measurements in determining metal resistivity. *Physics Education Research Journal*, 16(3), 205–215.
23. Menzel, S., Böttger, U., Wimmer, M., & Salinga, M. (2015). Physics of the switching kinetics in resistive memories. *Advanced functional materials*, *25*(40), 6306-6325.
24. Pacala, F. A. (2023). Curriculum theory and practice: A comparative literature review. *Ho Chi Minh City Open University Journal of Science-Social Sciences*, 13(2), 3–13.
25. Pacala, F. A. A. (2023, October). Artificial intelligence in a modernizing science and technology education: A textual narrative

synthesis in the COVID-19 era. In *Journal of Physics: Conference Series* (Vol. 2611, No. 1, p. 012028). IOP Publishing.

26. Pacala, F. A., & Pili, U. (2023). The Sound of G: A Method to Calculate The Acceleration Due to Gravity Using Acoustic Stopwatch. *Jurnal Pendidikan Fisika Indonesia*, *19*(2), 122-127.
27. Patil, J. J., Chae, W. H., Trebach, A., Carter, K. J., Lee, E., Sannicolo, T., & Grossman, J. C. (2021). Failing forward: Stability of transparent electrodes based on metal nanowire networks. *Advanced Materials*, *33*(5), 2004356.
28. Pazhooh, H. N., Bagheri, R., & Adloo, A. (2017). Fabrication of semi-conductive natural rubber nanocomposites with low copper nanoparticle contents. *Polymer*, *108*, 135-145.
29. Reyes, R., Pacala, F. A. A., Bengua, G., & Entac, E. (2024). The Correlation between Students' Insights and Academic Achievement in Science: A Predictor for STEM Career Path. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *14*(1).
30. Sabbah, A. K. (2021). *Microwave-Assisted Silver Nanoparticle Coating on 3D-Printed Denture Base Resin for Antifungal Purposes* (Doctoral dissertation, State University of New York at Stony Brook).
31. Schleder, G. R., Padilha, A. C., Acosta, C. M., Costa, M., & Fazzio, A. (2019). From DFT to machine learning: recent approaches to materials science–a review. *Journal of Physics: Materials*, *2*(3), 032001.
32. Snyder, P. J. (2018). *The Electronic Properties of Inorganic Materials and Their Influence on Cellular Behavior*. North Carolina State University.
33. Sumdani, M. G., Islam, M. R., Yahaya, A. N. A., & Safie, S. I. (2022). Recent advancements in synthesis, properties, and applications of conductive polymers for electrochemical energy storage devices: A review. *Polymer Engineering & Science*, *62*(2), 269-303.
34. Ushakov, V. Y. (2017). *Electrical power engineering: current state, problems and perspectives*. Springer.
35. Viegas, C., Pavani, A., Lima, N., Marques, A., Pozzo, I., Dobboletta, E., ... & Alves, G. (2018). Impact of a remote lab on teaching practices and student learning. *Computers & Education*, *126*, 201-216.
36. Wright, R. N. (2016). *Wire technology: process engineering and metallurgy*. Butterworth-Heinemann.
37. Wu, B., Pan, Z., Ding, D., Cuiuri, D., Li, H., Xu, J., & Norrish, J. (2018). A review of the wire arc additive manufacturing of metals: properties, defects and quality improvement. *Journal of manufacturing processes*, *35*, 127-139.
38. Yang, Z., Zhang, X., Lu, J., & Li, Y. (2022). Genetic analysis and identification of low‐resistivity gas reservoirs of southwestern Sulige gas field in China. *Energy Science & Engineering*, *10*(8), 2580-2592.
39. Zhang, C., Feiyang, W., & Wang, Y. (2024). Do you really know Ampere, Volt, and Ohm? *Paradigm: philosophical and cultural almanac, 4*(1), 123-134.
40. Zuza, K., Sarriugarte, P., Ametller, J., Heron, P. R., & Guisasola, J. (2020). Towards a research program in designing and evaluating teaching materials: An example from dc resistive circuits in introductory physics. *Physical Review Physics Education Research*, *16*(2), 020149.