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Implementation of Research-based Learning for Prospective Physics Teachers: A Case Study

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ABSTRACT Prospective physics teachers must have research skills because they will later utilize and transfer these skills throughout their teaching careers. However, research shows that students' research skills, including in Indonesia, are still low. In addition to equipping students with theoretical research knowledge, an emphasis is needed on the practical stage for prospective teachers in obtaining research skills. Using a reflective case study approach with qualitative methods, this research observes and describes the implementation of research-based learning for prospective physics teachers. The research-based learning was implemented through an experiment on resistance utilizing alternative tools and materials. Data was collected through participant observation from four participants, with the researcher as the main instrument. This study shows that the implementation of research-based learning provides an opportunity for prospective physics teachers to practice research skills and apply the scientific method to solve problems. More studies are needed regarding implementing research-based learning, especially in higher education.

Keywords: Research-based learning, Research skill, Scientific method, Prospective physics teacher

1. INTRODUCTION

The main goal of postgraduate programs is to develop students as competent researchers who have acquired the knowledge and skills to conduct and disseminate research in a particular research field (Meerah et al., 2012a). In addition, research skills are not only needed in the field of research. However, they are also needed in all fields of work that require the ability to gain new knowledge, understand phenomena with the help of scientific thinking skills, and act as active knowledge builders in society (Murtonen et al., 2008). A person with good research skills can also continuously develop professionally (Laidlaw et al., 2012). Therefore, research skills are essential for students to deal with increasingly complex real-life situations (Mitchell, 2009; Murdoch-Eaton et al., 2010; Huy & Thuy, 2021).

Apart from being an essential part of higher education, research is also becoming necessary in secondary education, especially science education (Kapon, 2016). Research skills in the context of science education refer to the ability to apply procedural and declarative knowledge to properly conduct scientific experiments (Turiman et al., 2012). Students need to have research skills because one of the main goals of the modern education system is to develop individuals who consume knowledge and produce advanced knowledge that reflects their critical, inquiring, creative attitude and respect for nature and humanity (Şahan & Tarhan, 2015). In addition to being owned by students, research skills also need to be owned by teachers because based on the results obtained from many studies that reveal the determinant effects of attitudes, behavior, and teacher skill levels on student performance (Oruç & Ulusoy, 2008; Şahin & Altınay, 2009), teachers are required to have an adequate level of knowledge about scientific research as well as skills and a positive attitude towards scientific research. For prospective teachers, having research skills and a positive attitude towards scientific research is very important in utilizing and transferring these skills throughout their teaching career (Taşdemir, 2013).

However, Harrison and Whalley (2008) question the extent to which students engage in research due to their previous years of undergraduate education. The literature indicates that many candidates enter graduate programs with weak prior knowledge and skills in conducting

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research (Meerah et al., 2012b). Students find it challenging to engage in research because no explicit attention has been paid in previous years to developing the skills required for success in research (DeHaan, 2009). The low level of research skills in Indonesia, both at secondary and tertiary education levels, is reflected in several studies which conclude that students as research subjects are still lacking in mastering research skills, especially in the aspects of using research methods, organizing research, answering research hypotheses, and publishing research results (Solihat et al., 2015; Roito et al., 2019; Nurlaelah et al., 2020).

Universities currently require their students, including prospective teachers, to take courses on the use of computers to find information and mandatory research methodology courses to benefit from and understand research. Universities have put in substantial resources and personnel to help students acquire research skills and prepare them as future human resource graduates who become knowledge-based workers (Meerah et al., 2012b). In addition, instead of simply transferring theoretical knowledge, more emphasis should be placed on the practical stage of acquiring research skills for prospective teachers (Şahan & Tarhan, 2015). This can be done by embedding research opportunities much earlier in the college curriculum in addition to the usual final-year project or dissertation (Walkington et al., 2011). However, there is little to no study regarding the implementation of research-based learning, especially in higher education. Therefore, this study aims to observe the implementation of research-based learning for prospective physics teachers in the form of projects at the end of the semester so that we can observe and further explore its effect on teaching and learning. The implementation of research-based learning was done through an experiment on resistance utilizing alternative tools and materials readily available daily. In the end, it is hoped that the implementation of research-based learning can contribute to improving the research skills of prospective physics teachers so that they can utilize and transfer these skills throughout their teaching careers.

2. METHOD

This research uses a reflective case study approach with a qualitative method. In the reflective case study approach, researchers need to emphasize the personal evaluative component in the form of reflective comments, detailed notes, or journals related to the research topic, as well as the feelings, problems, and researchers' reflections on experiences and interactions during the research (Hamilton & Corbett-Whittier, 2012). Therefore, the key instrument of this research is the researcher, collecting data through participant observation. Through this observation, the researcher collected data in the form of a detailed description of the actions taken by a group of prospective physics teachers in carrying out their final semester assignment, which was the application of research-based learning as well as the results reported by students to answer research questions assigned to them. Researchers have obtained consent from research subjects, so it can be ensured that one of the challenges in reflective case studies, namely ethical issues (Hamilton & Corbett-Whittier, 2012), can be avoided.

The validity and trustworthiness of case studies are frequently criticized (Riege, 2003; Street & Ward, 2012). For the case study's conclusions to be reliable, transportable, believable, and confirmable, the approach's trustworthiness—which encompasses both the validity and reliability dimensions—is essential (McGloin, 2008). Therefore, it is best to employ multiple cases with multiple participants (Quintão et al., 2020). Several teachers and students participated in this study. This is meant to look at the use of research-based learning from a variety of angles. Data was gathered through group interviews with teachers and students and individual interviews with academics. Parallel and conflicting themes emerged from the semi-structured interview-based thematic analysis of the case studies.

The application of research-based learning in this study is in the form of a final semester assignment for prospective physics teachers, with the primary objective being to analyze alternative resistors using materials that can be found easily. The students had the autonomy to arrange the research flow to be carried out. This task needed to be completed within two months in groups, with the final result in the form of an oral presentation and a research report paper. The group that was the subject of this study consisted of four students, two female students, and two male students. These participants were selected using the convenience sampling method because these participants met the practical criteria necessary for the study, such as ease of access, availability at a specific time, and willingness to participate (Dörnyei, 2007). These subjects were also easily accessible to researchers (Given, 2008). Since this research uses qualitative methods through participant observation, the researcher was directly involved in the activities carried out by the research subjects during the research (Musante & DeWalt, 2010).

3. FINDINGS

The main objective of the assignment given to students was to analyze alternative resistors using materials that can be found easily in daily life. After students understood the primary purpose of this task, they determined more specific objectives, namely 1) Making resistors from paper and graphite pencil strokes, 2) Measuring resistor resistance with various types of paper, 3) Measuring resistor resistance with variations in the length of graphite pencil strokes, 4) Measuring resistor resistance with variations in the number of graphite pencil strokes, 5) Calculating the resistivity of each resistor with various types of paper.

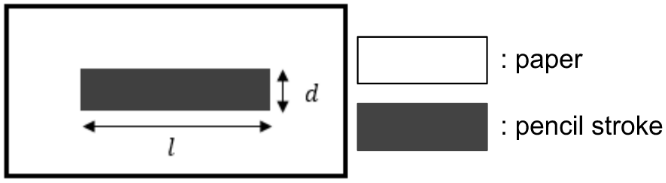


Figure 1 Design of paper resistor made by students

The method used by students in this task was experimental. The tools and materials chosen by the students were as follows: 1) 75 gsm white HVS paper, 2) 200 gsm white glossy art paper, 3) 150 gsm colored buffalo paper, 4) craft paper in the form of cardboard, 5) white parchment paper, 6) 2B pencil, 7) Ohm meter, 8) Lux meter, 9) ruler.

Before the research was carried out, the tools and materials were designed in such a way that they could be used following the research objectives. The design of the paper resistor is depicted in Figure 1. The primary materials of this resistor were paper as an insulator and graphite pencil strokes as a conductor. The pencil used was a 2B pencil because students found that based on previous research (Nurzaman et al., 2018), the resistivity of a 2B pencil is the median of the resistivity data compared to HB, 1B, 3B, and 4B pencils.

The research design began with constructing the resistors. Resistors were constructed based on the predetermined design. Furthermore, resistance data was collected based on variations in stroke length with stroke length as the independent variable, stroke width, number of strokes, and paper type as control variables, and the resistance value as the dependent variable. In addition, the experiment was also carried out by varying the number of strokes with the number of strokes as the independent variable, the stroke length, stroke width, and type of paper as control variables, and the resistance value as the dependent variable. The last experiment was carried out by varying the type of paper with the type of paper as the independent variable, the stroke length, stroke width, and the number of strokes as control variables, and the resistance value as the dependent variable. The resistivity of each resistor was also calculated using the adjusted Equation 1,

$$R = \rho \frac{l}{A} \quad [1]$$

where R is the resistance (Ω), ρ is the resistivity (Ωm), l is the cross-sectional length (m), and A is the cross-sectional area (m^2) (Sears et al., 2001). In simple terms, the research design compiled by students is presented in Figure 2.

There were three experiments with stroke length, number of strokes, and paper-type variations. The first experiment was to determine the resistance value R for variations in pencil stroke length. This was done by making pencil strokes on HVS paper with lengths of 1 cm, 2 cm, 3 cm, 4 cm, and 5 cm. Each length variation was etched with five strokes of a 2B pencil, and the stroke width was 0.3 cm. The number of strokes needs to be made the same because, based on previous studies, the number of strokes affects the resistance value of this alternative resistor (Nurzaman et al., 2018), while the length and width of the scratches influence the resistance value based on Equation 1. Each resistor with this variation in stroke length was measured for resistance (R) using an ohmmeter. The positive and negative ohmmeter probes were connected to each end of the stroke with different lengths so that the resistance value R was obtained from the ohmmeter reading, and this was repeated five times. Figure 3 shows the process of measuring the resistance of alternative resistors with variations in stroke length.

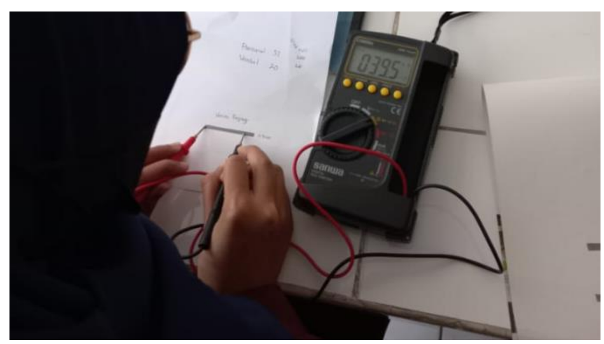


Figure 3 A student carried out the process of measuring alternative resistor resistance with variations in stroke length

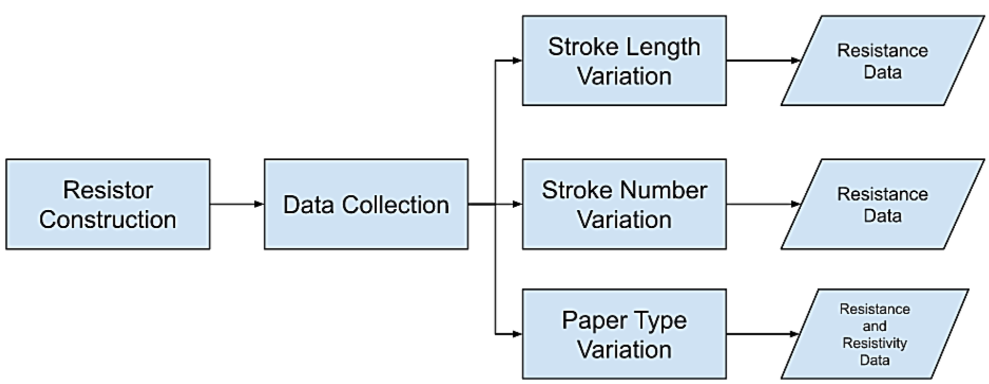
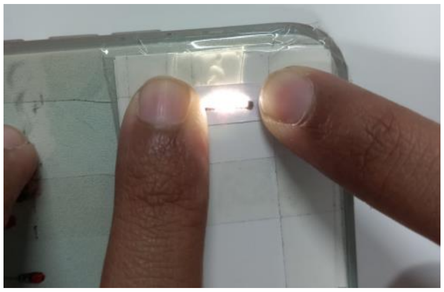
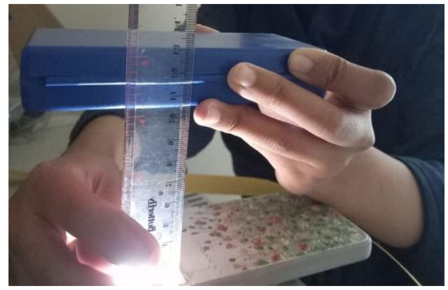


Figure 2 Research design compiled by students



(a)



(b)

Figure 4 Students measured the intensity of light that penetrates behind the resistor: a) light source, b) measurement process

The second experiment was to determine the effect of the number of pencil strokes on the resulting resistance value. This was done on HVS paper, given 2B pencil strokes with variations in the number of strokes of 0, 2, 4, 6, and 8, stroke length of 0.8 cm, and stroke width of 0.1 cm. Each variation of the thickness of the pencil strokes was measured for the translucency of light by shining a light on the paper that had been given the pencil strokes, and the intensity of the light that penetrated behind the paper was measured with a lux meter. Figure 4 measures light intensity that penetrates behind paper and pencil strokes. The resistance was measured using an ohmmeter by installing positive and negative probes at the ends of the strokes as in the previous experiment, and the measurement was repeated five times.

The third experiment was to determine the value of resistance *R* and resistivity *ϱ* for resistors with different paper types. This was done by streaking a 2B graphite pencil on HVS paper, art paper, buffalo paper, cardboard, and parchment paper. Each paper was etched with five strokes of a 2B pencil with a stroke width of 0.3 cm. The resistance of each resistor with this paper-type variation was measured using an ohmmeter for each stroke length of 1 cm, 2 cm, 3 cm, 4 cm, and 5 cm for five measurements each. The positive and negative ohmmeter probes were connected to each end of the stroke, so the resistance value *R* was obtained from the ohmmeter reading for each type of paper. Furthermore, with the resistance value *R*, the resistivity value was obtained by calculating it based on adjusted Equation 1. Figure 5 compares the types of paper used in this experiment.

After conducting a series of experiments, students analyzed the data to meet their research objectives. Students analyzed data quantitatively and qualitatively. The analysis results carried out by students were presented orally and included in a research report paper.

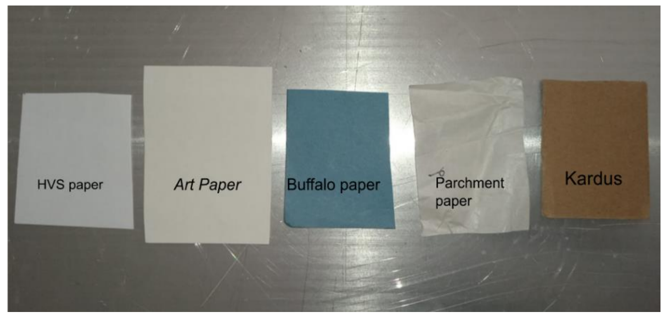


Figure 5 Comparison of the types of paper used

3.1 Results of Student Observations on Pencil Stroke Resistors with Variations in Stroke Length

The independent variable in this experiment was the length of the stroke; the control variables were the width of the stroke, the number of strokes, and the type of paper, while the dependent variable was the resistance value. The strokes made were 1 cm, 2 cm, 3 cm, 4 cm, and 5 cm long. The paper used was HVS paper; the number of strokes was five times the strokes of a 2B pencil, and the stroke width was 0.3 cm. The resistance value was measured five times using an ohmmeter, then the average was calculated. Table 1 shows data from the experiment conducted by students on pencil stroke resistors with variations in stroke length.

3.2 Results of Student Observations on Pencil Stroke Resistors with Variations in Stroke Number

The independent variable in this experiment was the number of strokes; the control variables were the stroke width, length, and paper type, while the dependent variable was the resistance value. The strokes made were 0, 2, 4, 6, 8. The paper used was HVS paper; the stroke length was 0.8 cm, and the width was 0.1 cm. Before measuring the

Table 1 Data from student experiments on pencil stroke resistors with variations in stroke length

Length (cm)	Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
1	41.8	39.2	38.3	39.5	39.3	39.6	1.30
2	72.8	70.8	72.3	72.1	79.8	73.6	3.56
3	97.6	98.3	98.6	98.2	98.9	98.3	0.48
4	136.3	137.9	136.3	138.1	136.1	136.9	0.97
5	170.0	167.0	169.1	169.8	170.2	169.2	1.31

resistance, the intensity of light that penetrated this resistor was measured using a lux meter to determine the effect of the number of pencil strokes on this resistor. Then, the resistance data on each resistor was obtained from the results of measurements using an ohmmeter five times. Table 2 presents data from the experiment conducted by students on pencil stroke resistors with variations in the number of strokes.

3.3 Results of Student Observations on Pencil Stroke Resistors with Variations in Paper Type

The independent variable of this experiment was the type of paper; the control variables were stroke length, width, and number of strokes, while the dependent variable was the resistance value. The paper materials were HVS, art paper, buffalo paper, cardboard, and parchment paper. Each paper was given 5 strokes with a 2B pencil and a stroke width of 0.3 cm. The resistance of each resistor with this paper-type variation using an ohmmeter for each stroke length of 1 cm, 2 cm, 3 cm, 4 cm, and 5 cm for five measurements each. Tables 3, 4, 5, 6, and 7 show data from experiments conducted by students on pencil stroke resistors with HVS paper, parchment paper, buffalo paper, cardboard, and art paper, respectively.

4. DISCUSSION

Before their final semester assignment, students studied the basics of resistors and capacitors. Next, students were assigned to analyze resistors made with simple materials. According to Diggle et al. (2011), the first stage in the scientific method is to determine research questions. In this study, students were able to develop research questions into specific objectives to be achieved, namely 1) Making resistors from paper and graphite pencil strokes, 2) Measuring resistor resistance with various types of paper, 3) Measuring resistor resistance with variations in the length of graphite pencil strokes, 4) Measuring resistor resistance with variations in the number of graphite pencil strokes, 5) Calculating the resistivity of each resistor with various types of paper.

According to Diggle et al. (2011), the next stage in the scientific method is designing an experiment. To achieve research objective number (1), students designed three experiments. Students determined the independent, control, and dependent variables from each experiment, which were also adjusted to the research objectives. To achieve goal number (2), students designed an experiment with variations in the length of pencil strokes. The independent variable in this experiment was the length of the stroke, the control variables were the width of the stroke, the number of strokes, and the type of paper, and the dependent variable was the resistance value. To achieve goal number (3), students designed an experiment with variations in the number of pencil strokes. The independent variable in this experiment was the number of strokes, the control variables were the stroke length, width, and paper type, and the dependent variable was the resistance value. Students designed experiments with various paper types to achieve goal number (4). The independent variable of this experiment was the type of paper; the control variables were stroke length, width, and number of strokes, and the dependent variable was the resistance value. In this experiment, students also calculated the resistivity of each resistor to achieve goal number (5). Students also designed tables to present their research data, which consist of Table 1 to Table 7.

After conducting experiments and collecting data, students must explore the data (Diggle et al., 2011) to answer research questions. Students performed exploratory data analysis to describe general patterns of variation in the data and to look for contingencies that might indicate problems in all the experiments performed. For the first experiment with variations in the length of pencil strokes, from the data in Table 1, the students described that the longer the pencil strokes, the more excellent the resistance.

Table 2 Data from student experiments on pencil stroke resistors with variations in stroke number

Number of Strokes (n)	Light Transmission Intensity (Lux)			Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
	Distance at		Average							
	8 cm	10 cm								
0	18.5	18.5	18.5	OL	OL	OL	OL	OL	OL	-
2	7	4	5.5	248	282	245	264	251	258	15.3
4	6	3	4.5	214	215	215	216	218	216	1.62
6	4	1	2.5	64.9	63.7	64.7	64.6	65.4	64.7	0.62
8	3	0.5	1.75	31.6	34.2	36.8	38.1	36.6	35.5	2.58

Table 3 Data from student experiment on pencil stroke resistor using HVS paper

Length (cm)	Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
1	41.8	39.2	38.3	39.5	39.3	39.6	1.30
2	72.8	70.8	72.3	72.1	79.8	73.6	3.56
3	97.6	98.3	98.6	98.2	98.9	98.3	0.49
4	136.3	137.9	136.3	138.1	136.1	136.9	0.97
5	170.0	167.0	169.1	169.8	170.2	169.2	1.31

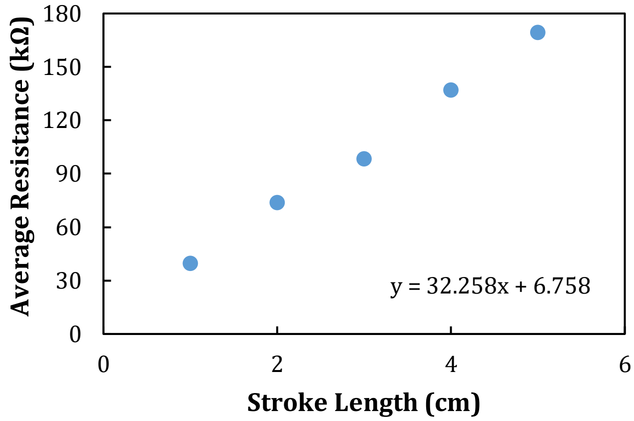


Figure 6 Graph of the relationship between stroke length and average resistance using HVS paper

This aligns with the findings of previous studies (Nurzaman et al., 2018; Inyeo & Wattanakasiwic, 2021). From these findings, students concluded that in this alternative resistor, the length of the pencil stroke is proportional to the resistance value. Students presented these findings in Figure 6.

Furthermore, in the second experiment, students confirmed that the number of strokes affected the strokes by measuring light translucency using a lux meter. Students found that the more strokes they made, the thicker the strokes they made. Therefore, the number of strokes affects the number of strokes they make. From the resistance data with variations in the number of strokes, students described that the thicker the scratches, the smaller the resistance of this resistor. Students concluded that the number of pencil strokes is inversely proportional to the value of the resistance of this alternative resistor and presented it in Figure 7. A Datum with the number of strokes 0 was used to compare, which indicated the result of OL or open loop on the ohmmeter. This means that scratchless paper has no continuity, which also means it has infinite resistance.

From the experimental data with various paper types in Table 3 to Table 7, students described that each resistor with different papers showed different resistance measurement results. Students made the following analysis.

Table 4 Data from student experiment on pencil stroke resistor using parchment paper

Length (cm)	Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
1	16.1	18.4	17.5	17.7	17.8	17.5	0.83
2	28.7	28.	28.8	28.8	28.8	28.7	0.12
3	38.4	38.4	38.5	38.8	38.9	38.6	0.23
4	55.9	54.3	54.1	54.2	52.5	54.2	1.20
5	63.4	63.0	64.4	64.4	63.5	63.7	0.63

Table 5 Data from student experiment on pencil stroke resistor using buffalo paper

Length (cm)	Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
1	37.6	44.3	39.9	47.1	48.4	43.5	4.61
2	81.7	81.7	81.5	81.0	79.9	81.2	0.76
3	119.8	117.9	118.0	119.3	120.0	119.0	0.99
4	154.6	152.7	152.8	153.6	152.6	153.3	0.85
5	189.4	193.0	188.4	190.3	190.2	190.3	1.71

Table 6 Data from student experiment on pencil stroke resistor using cardboard

Length (cm)	Resistance (kΩ)					Average Resistance (kΩ)	Standard Deviation (kΩ)
1	80.1	76.6	73.4	78.6	80.9	77.9	3.01
2	261.6	290.4	253.0	255.5	273.7	266.8	15.41
3	642.0	662.0	678.0	680.0	648.0	662.0	17.14
4	912.0	897.0	901.0	898.0	892.0	900.0	7.45
5	1000	989.0	989.0	965.0	992.0	987.4	13.61

Table 7 Data from student experiment on pencil stroke resistor using art paper

Length (cm)	Resistance (MΩ)					Average Resistance (MΩ)	Standard Deviation (MΩ)
1	18.4	15.6	12.6	13.6	16.8	15.4	2.358
2	20.9	20.9	23.0	22.2	22.4	21.9	0.930
3	30.0	30.1	31.0	31.0	31.7	30.7	0.717
4	34.9	34.5	34.7	34.3	34.5	34.6	0.251
5	39.6	38.8	38.9	38.8	38.6	38.9	0.394

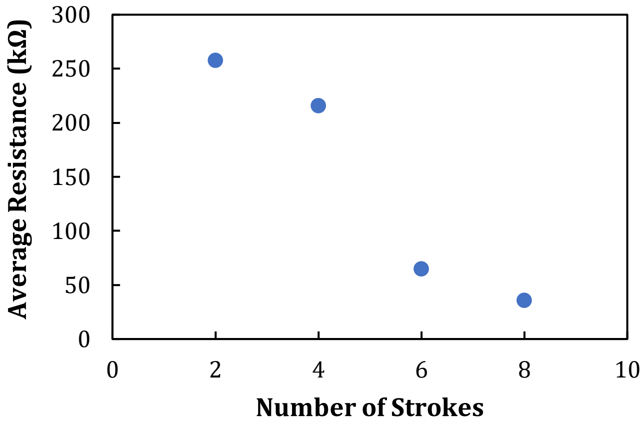


Figure 7 Graph of the relationship between the number of strokes and the average resistance

"Based on this research, the resistor with the greatest resistance and resistivity is the one using art paper. Judging from the specifications, art paper is the type of paper with the most additives because art paper is coated paper, where the art paper used in this study has a glossy coating. The art paper used is also relatively heavier than other paper, 200 gsm, which means that each unit area (m^2) of this paper weighs 200 grams. The second resistor with the greatest resistivity and resistance is the cardboard resistor. The specific weight of the craft paper used to make the cardboard is unknown, but qualitatively craft paper has higher strength than buffalo paper, parchment paper, and HVS so that craft paper has more additives. Following this resistor is the resistor using buffalo paper which has a texture like wood strokes with a weight of 150 gsm. The resistors with the relatively smallest resistance are the parchment paper and HVS resistors, where the HVS resistor has a larger resistance than the parchment paper resistors. The HVS paper used in this study weighed 75 gsm, while the exact weight of the parchment paper used was unknown, but in general parchment papers weigh 32 gsm/38 gsm/40 gsm. Even qualitatively, parchment paper looks and feels thinner than HVS paper."

From this analysis, students concluded that the type of paper affects the resistance value of this alternative resistor. In addition, students also calculated the resistivity of each resistor with the various types of paper. The resistivity of the resistor in this experiment was obtained from the stroke width value of 0.3 cm and the slope of the length against the resistance graph, as shown in Figure 6. This is based on Equation 1. Equation 1 was adjusted for calculations on the surface (2 dimensions) so that the equation becomes as follows.

$$\rho = R\frac{d}{l} \quad [2]$$

Where ρ is the resistivity (Ωcm), R is the resistance (Ω), l is the stroke length (cm), *and* d is the stroke width (cm). Therefore, the resistivity value of the HVS paper resistor is 9.68×10^3 Ωcm, the resistivity value of the parchment paper resistor is 3.54×10^3 Ωcm, the resistivity value of the buffalo paper resistor is 1.10×10^4 Ωcm, the cardboard resistor resistivity value is 7.36×10^4 Ωcm, and the resistivity value of the art paper resistor is 1.79×10^6 Ωcm.

In the end, the students concluded that the resistance value of these alternative resistors depends on the length of the strokes, the number of strokes, and the type of paper. The more additives in the paper, such as hardeners, coatings, and dyes, the more excellent the resulting resistance and the greater the resistivity. The length of the stroke on the paper is proportional to the resistance, so if a resistor with a large resistance is needed, the length of the pencil stroke needs to be extended—conversely, the greater the number of pencil strokes, the smaller the resistance. Students also realized that other factors, such as human error and errors in the measurement system itself, can influence the measurement of these resistances. Students explained that the strength of the hand when making the strokes also affected the value of the resistance, which might be different for each stroke in this experiment. In addition, students explained that the curvature of the paper also influences the resistance value (Inyeo & Wattanakasiwic, 2021).

5. CONCLUSION

Applying research-based learning for prospective physics teachers allows them to practice research skills and apply the scientific method to solve problems. They were able to determine research questions, design experiments to answer research questions, explore data, analyze data, and make conclusions from research results. Students could present data through tables and graphs in exploring and analyzing data. These tables and graphs help students conclude that the resistance values of alternative resistors depend on the length of the strokes, the number of strokes, and the type of paper. In addition, students were also able to realize that the measurements in this study can be influenced by other factors, such as human error or errors in the measurement system itself, and explain the possible causes. From the results of these observations, the researchers are optimistic that implementing research-based learning can contribute to improving the research skills of prospective physics teachers so that they can utilize and transfer these skills throughout their teaching careers. More research needs to be carried out regarding research-based learning, especially in higher education settings for prospective teachers.

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