The Effect of the Proteus Virtual Inquiry Laboratory Model on Students' Scientific Reasoning and Problem-Solving at SMAN 06 Bombana

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Abstract

This study aims to determine the effect of implementing the Proteus-Based Virtual Inquiry Laboratory Model on the scientific reasoning and problem-solving skills of Grade XII students in the topic of series–parallel circuits at SMA Negeri 06 Bombana. The study employed a pre-experimental design (one-group pretest–posttest) with a sample of 25 students. Data were collected through essay tests and observations, then analyzed descriptively and inferentially. The results showed a significant improvement in scientific reasoning skills (problem identification, hypothesis formulation, variable control, data analysis, and conclusion drawing) as well as problem-solving skills (understanding the problem, planning strategies, performing calculations, and evaluating results). The integration of inquiry stages with Proteus simulations provided a more active and meaningful learning experience. Thus, this model is effective as an alternative approach to physics learning in schools with limited laboratory facilities.

Keywords: *Virtual Inquiry Laboratory, Proteus, Problem-Solving.*

A. INTRODUCTION

The development of science and technology in the 21st century has had a significant impact on the education system, including in Indonesia. The learning process today does not only emphasize the mastery of information but also aims to improve competencies relevant to the 21st century, such as critical thinking, creativity, communication skills, collaboration, scientific reasoning, and problem-solving skills. Science and technology in the 21st century have brought about major transformations in education, including in Indonesia. Learning is no longer focused solely on acquiring knowledge but rather on developing the competencies required in the 21st century, such as critical thinking, creativity, communication, collaboration, scientific reasoning, and problem-solving (Fitriah & Zawanis, 2024).

Physics is a natural science discipline that investigates natural phenomena through scientific research methods. The essence of physics learning is not only focused on mastering facts, principles, laws, and theories but also on improving scientific process skills, such as observation, hypothesis formulation, experimental design, data analysis, and drawing conclusions based on available data. Therefore, the physics learning process must provide students with opportunities to directly experience how knowledge is obtained through scientific activities, so that the

concepts learned have deeper meaning and are not limited to memorization. Learning that focuses on the delivery of material by teachers tends to result in superficial understanding and provides insufficient opportunities to develop scientific thinking skills (Aulia, Adawiah, & Lutfiatussolihah, 2024).

One of the main competencies in physics learning is scientific reasoning. Scientific reasoning is the ability to apply scientific principles to understand phenomena, identify cause-and-effect relationships, design research, control variables, evaluate evidence, and draw logical conclusions based on available data (Lawson, 2000). This ability serves as a foundation for developing a proper understanding of concepts and preventing misconceptions about physical phenomena. Students with good scientific reasoning skills tend to find it easier to understand complex concepts, relate theories to real-world events, and make decisions based on scientific evidence compared to those who rely solely on memorizing concepts (Putri, 2025).

In addition to scientific reasoning, problem-solving skills are also essential abilities in physics education. These skills include understanding problems, identifying relevant information, selecting appropriate physics concepts, planning strategies, performing calculations systematically, and evaluating the resulting solutions. Problem-solving skills are not only required to solve physics problems at school but also serve as preparation for facing life challenges that require logical, analytical, and structured thinking. Various studies have shown that learning methods based on experiments, research, and active inquiry are much more effective in improving problem-solving skills than learning models that focus on teacher-centered instruction (Islamiyah, Sujito, & Nasikhudin, 2025).

The development of scientific reasoning and problem-solving skills is crucial in the topic of series and parallel circuits. This topic requires students not only to understand the basic principles of electricity (current, voltage, resistance, and power) but also to be able to explain the relationships between variables in circuits and apply them to solve contextual problems. The abstract nature of electrical topics, as circuit processes are difficult to observe directly, often creates challenges for students in understanding concepts, distinguishing the characteristics of series and parallel circuits, and explaining the effects of component changes on the entire circuit (Alhinduan SR, 2016), (Azisah R, 2015), (Novitasari I, 2017), (Theasy Y, 2018), . These difficulties affect students' low levels of scientific reasoning and problem-solving skills in electrical topics (Akbar, Annovasho, & Mardaya, 2023).

The results of preliminary observations and interviews with physics teachers indicate that the learning methods used for series-parallel circuit materials are still dominated by lectures, discussions, and problem-solving exercises. Practical activities have not been carried out optimally due to limitations in equipment, electronic components, and available learning time. As a result, students obtain more information from teachers rather than conducting independent exploration. This situation causes difficulties in explaining the relationships between current, voltage, and resistance, predicting changes in circuit characteristics, and applying concepts to

solve contextual problems. Therefore, the learning process has not fully supported the development of students' scientific reasoning and problem-solving skills.

One solution to overcome the limitations of practical activities is the use of virtual laboratories. A virtual laboratory is a computer-based learning environment that allows students to conduct interactive experimental simulations similar to real-life laboratory practices (Cesariyanti Y, 2022). Unlike traditional laboratories, virtual laboratories allow experiments to be conducted repeatedly without being constrained by the availability of equipment, materials, or time. Various studies have shown that the use of virtual laboratories can improve conceptual understanding, learning motivation, higher-order thinking skills, and the effectiveness of physics instruction because students can visualize abstract phenomena that are difficult to observe directly (Fitriah & Zawanis, 2024).

One application frequently used in learning electronics and electrical systems is Proteus Design Suite. Proteus provides users with the opportunity to design, test, and analyze various circuits virtually. By using this application, students can create both series and parallel circuits, adjust resistance values or voltage sources, and directly observe changes in current, voltage, and circuit characteristics without the risk of damaging components. This visualization capability makes Proteus an effective learning tool for helping students understand abstract electrical concepts. The results of a meta-analysis (Akbar, Annovasho, & Mardaya, 2023) indicate that the use of Proteus in physics learning has a positive effect on students' learning outcomes at various educational levels.

Although the use of learning tools such as virtual laboratories is very helpful in making abstract concepts easier to understand, the development of students' scientific thinking skills still requires support from an appropriate learning model. One model that suits these needs is the Virtual Inquiry Laboratory, which is an approach that combines inquiry-based learning steps with the use of virtual laboratories. Through this model, students do not merely conduct simulations but are also trained to identify problems, formulate hypotheses, conduct virtual experiments, collect and analyze data, and draw conclusions based on available evidence. In this way, the learning process is not only focused on mastering concepts but also simultaneously improves scientific reasoning and problem-solving skills

Various previous studies have reported that virtual laboratory-based learning has a positive impact on improving students' learning outcomes, conceptual understanding, and science process skills. A literature review (Aulia, Adawiah, & Lutfiatussolihah, 2024) concluded that the integration of virtual laboratories with inquiry models can improve student engagement, conceptual understanding, and scientific activities. In addition, a meta-analysis (Fitriah & Zawanis, 2024) showed that the use of virtual laboratories has a significant effect on improving conceptual understanding and higher-order thinking skills in physics learning. Another study (Akbar, Annovasho, & Mardaya, 2023) also emphasized that the use of Proteus is effective in improving learning outcomes because it can visualize abstract concepts in electrical materials.

Although many studies have shown that virtual laboratories and Proteus are effective in improving learning outcomes, conceptual understanding, and science process skills, most studies still place greater emphasis on cognitive aspects. Research that specifically explores the impact of the Proteus-based Virtual Inquiry Laboratory Model on scientific reasoning and problem-solving skills simultaneously, particularly in series and parallel circuit materials at the senior high school level, remains limited. Furthermore, most studies have been conducted in schools with adequate laboratory facilities, while studies in schools experiencing facility limitations, such as SMA Negeri 06 Bombana, are still very limited. This situation indicates a research gap that needs to be investigated more thoroughly

This study presents an innovation in the form of using the Proteus-based Virtual Inquiry Laboratory Model, which does not rely solely on virtual simulations as a learning medium but also integrates inquiry steps to advance two important competencies in the 21st century, namely scientific reasoning and problem-solving in the topic of series and parallel circuits. The results of this study are expected to make significant theoretical and practical contributions. In addition, this study is conducted in the real context of SMA Negeri 06 Bombana, which faces limitations in laboratory facilities, so the research findings are expected to provide an alternative learning solution that is more effective, efficient, and easy to implement in schools with similar conditions.

Theoretically, this study is expected to contribute to a better understanding of the implementation of the Proteus-based Virtual Inquiry Laboratory in physics education, particularly in terms of developing scientific reasoning and problem-solving skills. In practice, this study can serve as an alternative learning model for physics teachers to optimize the teaching of series and parallel circuit materials, especially in educational institutions with limited laboratory facilities. For students, the implementation of this model is expected to improve the quality of their learning experiences through more active scientific inquiry activities, so that they can not only understand concepts but also apply this understanding to solve various physics problems logically and systematically.

Based on the description above, it is necessary to conduct a study entitled "The Effect of Implementing the Proteus-Based Virtual Inquiry Laboratory Model on the Scientific Reasoning and Problem-Solving Skills of Grade XII Students on Series and Parallel Circuit Materials at SMA Negeri 06 Bombana."

The objectives of this study are to explore the impact of implementing the Proteus-based Virtual Inquiry Laboratory Model on the scientific reasoning abilities of Grade XII students in the topic of series and parallel circuits at SMA Negeri 06 Bombana, to investigate the effect of implementing the Proteus-based Virtual Inquiry Laboratory Model on the problem-solving skills of Grade XII students in series and parallel circuit materials at SMA Negeri 06 Bombana, and to analyze the extent to which the implementation of the Proteus-based Virtual Inquiry Laboratory Model can improve the scientific reasoning and problem-solving skills of Grade XII students in series and parallel circuit materials at SMA Negeri 06 Bombana.

The findings of this study are expected to contribute to the advancement of educational science, particularly in the field of physics education, in relation to the implementation of the Proteus-based Virtual Inquiry Laboratory Model in the teaching and learning process. This study also enriches the scientific literature on the development of scientific thinking skills and problem-solving skills through inquiry-based learning methods supported by virtual laboratory technology.

The findings of this study are also expected to serve as an academic reference for future researchers in developing learning models focused on virtual laboratories, using Proteus software as a supporting tool, and conducting research related to improving scientific thinking and problem-solving skills in physics learning.

The results of this study are expected to provide a more active, interactive, and meaningful learning experience through the implementation of the Proteus-based Virtual Inquiry Laboratory Model. In addition, this study aims to improve scientific thinking skills, problem-solving skills, understanding of series-parallel circuits, as well as students' motivation and engagement in physics learning activities.

This study is expected to serve as an alternative innovative teaching method for delivering series-parallel circuit materials. The findings of this study can also help teachers overcome the lack of laboratory facilities by using Proteus software as a virtual laboratory, enabling the learning process to become more effective, efficient, and student-centered.

This study is expected to serve as a consideration for schools in developing technology-based physics learning methods, particularly by utilizing virtual laboratories to support practical activities. The results of this study are also expected to encourage improvements in educational quality and serve as a reference for providing learning media that are in line with advances in educational technology.

This study is expected to broaden the researcher's knowledge, experience, and skills in designing, implementing, and evaluating physics learning that adopts the Proteus-based Virtual Inquiry Laboratory Model. In addition, this study also serves as a means of improving competencies in the field of physics education research and as a foundation for further relevant research.

The findings of this study are expected to serve as an academic reference and source of information for other researchers conducting similar studies. This study also has the potential to serve as a foundation for developing virtual laboratory-based learning models for other physics topics and at various educational levels.

B. METHOD

This study applies a quantitative approach with a Pre-Experimental Design, which aims to examine the impact of implementing the Proteus-based Virtual Inquiry Laboratory Model on students' scientific reasoning skills and problem-solving abilities through pretest–posttest data analysis. According to Creswell (2018), quantitative research is used to evaluate theories by measuring relationships between variables through research instruments and statistical analysis.

The research design employed is the One Group Pretest–Posttest Design, in which one group of participants undergoes a pretest before the treatment and a posttest after the treatment (Sugiyono, 2022). The selection of this design is based on the situation at SMA Negeri 06 Bombana, which only has one Grade XII class as the research subject; therefore, all students are selected as the sample. Although there is no control group, this design is still capable of providing an overview of the impact of implementing the model by comparing learning outcomes before and after the treatment.

The One Group Pretest–Posttest Design can be illustrated as follows.

Table 1. One Group Pretest–Posttest Design

Pretest	Perlakuan	Posttest
O_1	X	O_2

Source: Sugiyono (2022)

Description:

- O_1: Pretest of scientific reasoning skills and problem-solving abilities.
- X: Learning using the Proteus-based Virtual Inquiry Laboratory Model.
- O_2: Posttest of scientific reasoning skills and problem-solving abilities.

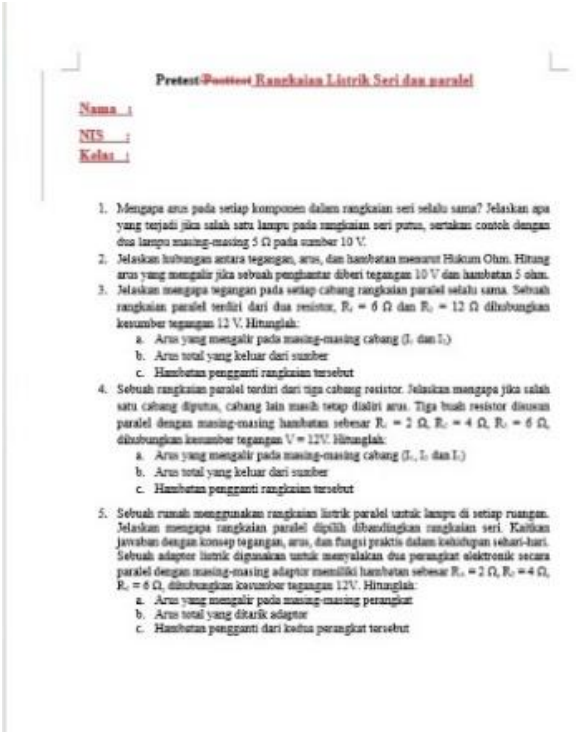
The difference between the pretest (O_1) and posttest (O_2) results is used to evaluate the impact of implementing the Proteus-based Virtual Inquiry Laboratory Model on students' scientific reasoning skills and problem-solving abilities. Furthermore, the data are analyzed using descriptive and inferential statistics in accordance with the established research objectives.

This research was conducted at SMA Negeri 06 Bombana, a school located in Rakadua Village, Poleang Barat District, Bombana Regency. The research was conducted from June 15, 2026, to August 15, 2026.

Research instruments are tools used to obtain data in accordance with the research objectives. Good instruments must meet the requirements of validity and reliability to produce accurate and accountable data (Arikunto, 2021), (Farida, 2021) & (Widoyoko, 2016) . According to Sugiyono (2022), an instrument is a tool used to measure natural and social phenomena, while Creswell (2018) emphasizes that instruments are used to collect data so that research variables can be measured accurately.

The instruments used in this study consist of:

1. Tests of Scientific Reasoning and Problem-Solving Abilities (Pretest and Posttest).
2. Observation sheets for assessing the implementation of learning.

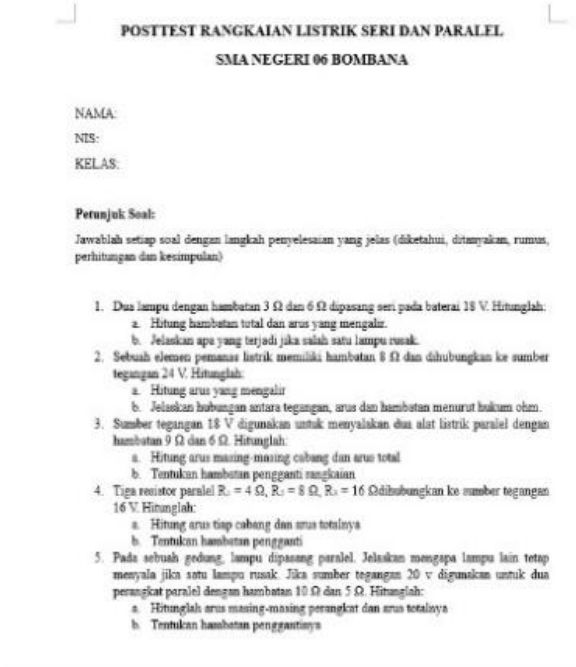


Pretest ~~Posttest~~ Rangkaian Listrik Seri dan paralel

Nama :
NIS :
Kelas :

1. Mengapa arus pada setiap komponen dalam rangkaian seri selalu sama? Jelaskan apa yang terjadi jika salah satu lampu pada rangkaian seri putus, sertakan contoh dengan dua lampu masing-masing 5 Ω pada sumber 10 V.
2. Jelaskan hubungan antara tegangan, arus, dan hambatan menurut Hukum Ohm. Hitung arus yang mengalir jika sebuah penghantar diberi tegangan 10 V dan hambatan 5 ohm.
3. Jelaskan mengapa tegangan pada setiap cabang rangkaian paralel selalu sama. Sebuah rangkaian paralel terdiri dari dua resistor, R_1 = 6 Ω dan R_2 = 12 Ω dihubungkan kesumber tegangan 12 V. Hitunglah:
   a. Arus yang mengalir pada masing-masing cabang (I_1 dan I_2)
   b. Arus total yang keluar dari sumber
   c. Hambatan pengganti rangkaian tersebut
4. Sebuah rangkaian paralel terdiri dari tiga cabang resistor. Jelaskan mengapa jika salah satu cabang diputus, cabang lain masih tetap dialiri arus. Tiga buah resistor disusun paralel dengan masing-masing hambatan sebesar R_1 = 2 Ω, R_2 = 4 Ω, R_3 = 6 Ω, dihubungkan kesumber tegangan V = 12V. Hitunglah:
   a. Arus yang mengalir pada masing-masing cabang (I_1, I_2 dan I_3)
   b. Arus total yang keluar dari sumber
   c. Hambatan pengganti rangkaian tersebut
5. Sebuah rumah menggunakan rangkaian listrik paralel untuk lampu di setiap ruangan. Jelaskan mengapa rangkaian paralel dipilih dibandingkan rangkaian seri. Kaitkan jawaban dengan konsep tegangan, arus, dan fungsi praktis dalam kehidupan sehari-hari. Sebuah adaptor listrik digunakan untuk menyalakan dua perangkat elektronik secara paralel dengan masing-masing adaptor memiliki hambatan sebesar R_1 = 2 Ω, R_2 = 4 Ω, R_3 = 6 Ω, dihubungkan kesumber tegangan 12V. Hitunglah:
   a. Arus yang mengalir pada masing-masing perangkat
   b. Arus total yang ditarik adaptor
   c. Hambatan pengganti dari kedua perangkat tersebut

Figure 1. Pretest instrument



POSTTEST RANGKAIAN LISTRIK SERI DAN PARALEL

SMA NEGERI 06 BOMBANA

NAMA:

NIS:

KELAS:

Petunjuk Soal:

Jawablah setiap soal dengan langkah penyelesaian yang jelas (diketahui, ditanyakan, rumus, perhitungan dan kesimpulan)

1. Dua lampu dengan hambatan 3 Ω dan 6 Ω dipasang seri pada baterai 18 V. Hitunglah:
   a. Hitung hambatan total dan arus yang mengalir.
   b. Jelaskan apa yang terjadi jika salah satu lampu rusak.
2. Sebuah elemen pemanas listrik memiliki hambatan 8 Ω dan dihubungkan ke sumber tegangan 24 V. Hitunglah:
   a. Hitung arus yang mengalir
   b. Jelaskan hubungan antara tegangan, arus dan hambatan menurut hukum ohm.
3. Sumber tegangan 18 V digunakan untuk menyalakan dua alat listrik paralel dengan hambatan 9 Ω dan 6 Ω. Hitunglah:
   a. Hitung arus masing-masing cabang dan arus total
   b. Tentukan hambatan pengganti rangkaian
4. Tiga resistor paralel R_1 = 4 Ω, R_2 = 8 Ω, R_3 = 16 Ωdihubungkan ke sumber tegangan 16 V. Hitunglah:
   a. Hitung arus tiap cabang dan arus totalnya
   b. Tentukan hambatan pengganti
5. Pada sebuah gedung, lampu dipasang paralel. Jelaskan mengapa lampu lain tetap menyala jika satu lampu rusak. Jika sumber tegangan 20 v digunakan untuk dua perangkat paralel dengan hambatan 10 Ω dan 5 Ω. Hitunglah:
   a. Hitunglah arus masing-masing perangkat dan arus totalnya
   b. Tentukan hambatan penggantinya

Figure 2. Post-test instrument

Data collection was carried out through **tests** and **observation**. Tests were used to obtain data on students' scientific reasoning skills and problem-solving abilities, while observation was used to assess the implementation of learning using the Proteus-based Virtual Inquiry Laboratory Model. This technique was selected because it is consistent with the research objectives and is capable of providing relevant information regarding the variables being studied (Sugiyono, 2022); (Creswell, 2018).

C. RESULTS AND DISCUSSION

Tabel 2. Data Analysis Table

Student Name	Pretest	Posttest	N-Gain	Maximum Score
Ahmad Pratama	90	95	0,5	100
Elisa	80	90	0,5	100
Etri Nur Amri	95	100	1	100
Alyatul Muthmainnah	65	98	0,942857	100
Muhammad Ashraf Fawzi	94	100	1	100
Tasya	84	84	0	100
Arham	90	90	0	100
Andi Nurliana	86	92	0,428571	100
Risna Jayanti	96	98	0,5	100
Ummul Fadhillah Ummah	94	95	0,166667	100
Muhammad Lutfi	86	90	0,285714	100
Arnis	86	90	0,285714	100
Fauzia Khairun Nisa	76	80	0,166667	100
Fausia	90	90	0	100
Maniati	68	75	0,21875	100
Misra	42	70	0,482759	100
Fitri	56	70	0,318182	100
Irwansyah	58	70	0,285714	100
Anisa Ramadhani	90	90	0	100
Buhari Harun	74	80	0,230769	100
Nita	96	90	1,5	100
Try Resky Amelia	68	75	0,21875	100
Rahmi. R	84	90	0,375	100
Muhammad Faizal	96	96	0	100

The data analysis table above shows that the pretest scores ranged from 42 to 96, while the posttest scores increased for most students, ranging from 70 to 100. Some students demonstrated significant improvement (for example, Alyatul Muthmainnah, from 65 to 98), while others showed no improvement or a decrease in scores (for example, Nita, from 96 to 90).

The N-Gain value was calculated to measure the effectiveness of the learning process.

Table 2. N-Gain Interpretation Criteria.

N-Gain Value	Category
≥0,70	High
0,30≤ N-Gain <0,70	Moderate
N-Gain <0,30	Low

Source: Hake (1999).

Students classified in the high category (g ≥ 0.70) include Alyatul Mutmainnah, with an N-Gain score of 0.94. Etri Nur Amri and Muhammad Ashraf Fawzi showed

equivalent improvements, with N-Gain scores of 1. Students classified in the moderate category ($0.30 \leq g < 0.70$) include Ahmad Pratama and Elisa, both with an N-Gain score of 0.5; Misra, with an N-Gain score of 0.48; Rahmi R., with an N-Gain score of 0.375; Fitri, with an N-Gain score of 0.318; and Andi Nurliana, with an N-Gain score of 0.428. Students classified in the low category include Ummul Fadhillah Ummah and Fauzia Khairun Nisa, who showed the same improvement with an N-Gain score of 0.16; Masniati and Try Rezky Amelia, with N-Gain scores of 0.21; Buhari Harun, with an N-Gain score of 0.23; and Irwansyah, Muhammad Lutfhi, and Arnis, all with N-Gain scores of 0.28. There were also students who showed no improvement ($g = 0$), namely Tasya, Arham, Fauzia, Anisa Ramadhani, and Muhammad Faizal. Meanwhile, another student, Nita, experienced a decline ($g < 0$), with an N-Gain score of -1.5.

In general, most students showed improvements in learning outcomes within the moderate to high categories. However, the presence of several students with low or zero N-Gain scores indicates the need for special attention to more tailored learning strategies. A decline in scores may serve as a significant indicator that not all students responded well to the treatment, thus requiring an analysis of external factors such as motivation, learning conditions, or technical errors.

Thus, it can be concluded that the data analysis of the implementation of the Proteus-based virtual laboratory inquiry learning model had a positive effect on improving students' learning outcomes. This is evident from the N-Gain scores, most of which fell within the moderate to high categories. Three students achieved N-Gain scores approaching 1, indicating optimal improvement. However, several students had low or even negative N-Gain scores, indicating the need for further evaluation of the factors affecting learning outcomes. Overall, the data support the hypothesis that effective learning treatment can improve students' understanding.

D. CONCLUSION

The implementation of the Proteus-Based Virtual Inquiry Laboratory Model has been proven to improve the scientific reasoning and problem-solving skills of Grade XII students on the topic of series–parallel circuits at SMA Negeri 06 Bombana. Students became more capable of identifying problems, formulating hypotheses, controlling variables, analyzing data, and drawing scientific conclusions. They also demonstrated greater proficiency in understanding problems, selecting appropriate concepts, developing strategies, and systematically evaluating results.

ACKNOWLEDGMENTS

The authors express their gratitude to Allah SWT for His mercy and blessings, which enabled the successful completion of this research. The authors would also like to thank their academic supervisors, the physics teacher at SMA Negeri 06 Bombana, and their friends for the guidance, support, and assistance provided throughout the research process. The authors also extend their gratitude to the school for facilitating this research, enabling all stages of the process to proceed smoothly. May all the

assistance provided be duly rewarded by Allah SWT.

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