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# Implementation of Virtual Laboratory-Based Interactive Learning Media for Students' Science Literacy Skills on Temperature and Heat Material

Perlis Tantalama, Tirtawaty Abdjul*, Nurhayati Nurhayati, Abdul Haris Odja, Muhammad Yusuf

Department of Science Education, Faculty of Mathematics and Natural Sciences, Gorontalo State University, Gorontalo, Indonesia
*e-mail: tirtawaty@ung.ac.id

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**Abstract:** The low scientific literacy of students in Indonesia is caused by the monotonous learning process that makes students bored with learning. This study aims to determine the effect of a virtual laboratory based on PhET simulation on students' scientific literacy in temperature and heat. This study used a quasi-experimental, non-equivalent control-group design with two experimental and two control classes of seventh-grade students during the 2025/2026 academic year. Data were collected using pre-test and post-test scientific literacy instruments. The results of the independent-samples t-test showed a significance value (Sig. 2-tailed) of 0.000 < 0.05, indicating a significant effect of the virtual laboratory on students' scientific literacy. In addition, the N-Gain analysis showed that the control class was in the low category (0.17 and 0.14), while the experimental class was in the medium category (0.63). The uniqueness of this study lies in integrating a virtual laboratory based on PhET simulations with scientific literacy indicators in teaching temperature and heat. These findings indicate that virtual laboratory media can effectively improve students' scientific literacy. PhET simulation-based virtual laboratories can serve as an effective technology-enhanced learning tool to improve students' scientific literacy, particularly in understanding temperature and heat concepts in junior high school science education.

**Keywords:** virtual laboratory, PhET simulations, science literacy, temperature and heat, interactive learning materials.

## Introduction

In the modern era, advances in science and technology have had a significant impact on various aspects of life, including science education. Science is a discipline that develops through processes such as observation, problem identification, hypothesis formulation, experimentation, and the formation of concepts and theories [1]. In the learning process, teachers act as facilitators who can integrate technology to create effective and interactive learning experiences that align with the demands of the 21st century. Improving teachers' competence in using educational technology is crucial to ensure students develop critical and logical thinking skills and are prepared to face future challenges [2].

One of the key competencies in science education is scientific literacy. This skill is important because it helps students understand various real-world issues related to the environment, health, technology, economics, and society [3]. Scientific literacy also serves as a foundation for students to make decisions based on scientific knowledge in everyday life [4].

However, students' scientific literacy skills in Indonesia remain relatively low. According to the 2022 Program for International Student Assessment (PISA), Indonesia achieved an average scientific literacy score of 383, ranking 67th out of 81 participating countries, still far below the global average of 485 [5]. Despite an improvement in ranking compared to 2018, Indonesia's scientific literacy score declined by 13 points. These results indicate that students' scientific literacy skills have not developed optimally [6].

According to PISA, scientific literacy encompasses three main indicators: identifying scientific issues or questions, explaining phenomena scientifically, and using scientific evidence to draw conclusions [3]. These three indicators require students not only to understand theory but also to be able to conduct investigations, analyze data, and connect scientific concepts to real-world phenomena.

One alternative is virtual laboratory-based learning media. A virtual laboratory is a digital learning tool that simulates laboratory practicum activities, allowing students to conduct experiments virtually as if they were in a real laboratory. This media can overcome the limitations of equipment, materials, time, and costs of practicums, while providing a more flexible and interactive learning experience [7]. One widely used virtual laboratory platform is PhET (Physics Education Technology), an interactive simulation tool that helps students understand abstract concepts in science through visualization and virtual experiments. Previous research has shown that PhET is effective in improving students' conceptual understanding and engagement in science learning [8].

Implementing PhET simulations using the Problem-Based Learning model can improve student learning outcomes [9]. However, this research focuses more on cognitive learning outcomes and does not specifically analyze scientific literacy indicators. Virtual laboratory-based learning media using a differentiated learning approach can improve students' scientific literacy [10]. In addition, previous studies have used few quasi-experimental

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designs that directly compare experimental and control classes to assess the effectiveness of PhET-based virtual laboratories on temperature and heat at the junior high school level.

Based on the introduction above, there remains a research gap regarding the use of PhET-based virtual laboratories that specifically integrate scientific literacy indicators into materials on temperature and heat. The novelty lies in integrating PhET simulations with students' scientific literacy indicators through a quasi-experimental design to examine the effect of virtual laboratory use on the ability to identify scientific problems, explain scientific phenomena, and use scientific evidence regarding temperature and heat at the junior high school level.

## Research Methods

This research was conducted at SMP Negeri 1 Suwawa and SMP Negeri 2 Suwawa, located in Suwawa District, Bone Bolango Regency, Gorontalo Province, during the odd semester of the 2025/2026 academic year. The study lasted for approximately one semester. The method used was a quasi-experimental design involving an experimental class and a control class to determine the effect of the treatment given to the groups receiving different treatments [11].

The research design used a Non-equivalent Control Group Design. This design involves an experimental and a control group, with students not randomly assigned to either, but both groups receive pre- and post-tests to measure changes in students' scientific literacy before and after treatment. In this design, there are two groups: one that receives the treatment and the other that serves as the control group. Both groups are given a pre-test and a post-test [12].

The research population consisted of all seventh-grade students at the two schools, with each school having four classes. The population is the entire research area that includes objects or subjects with specific characteristics and qualities determined by the researcher [13]. The sampling technique used was purposive sampling with intact groups. In each school, two control and two experimental classes were selected as research samples, based on equal student academic abilities (as determined by previous science scores), equal student numbers, and recommendations from science teachers. The intact group technique was chosen because it is in line with the conditions of educational research in schools, where full individual randomization is generally not possible [14].

This study administered a pre-test to both the experimental and control groups. Next, the experimental group received a virtual laboratory treatment using a PhET simulation on temperature and heat, aligned with scientific literacy indicators. In addition, the control group was given conventional methods, such as lectures, discussions, and textbooks, without the aid of a virtual laboratory [15]. After the entire learning process was completed, both groups took a post-test to assess students' scientific literacy skills following the treatment. Instrument validity testing used Product-Moment correlation in Microsoft Excel at a 5% significance level. The instrument is declared valid if the calculated r value is greater than the table r value [16]. Next, reliability testing uses the Cronbach's Alpha coefficient. The instrument is considered reliable if it has a high reliability coefficient value.

The normality test used the Shapiro-Wilk test with IBM SPSS Statistics because the sample size was less than 50 students [17]. The homogeneity test, using the Levene test with the help of IBM SPSS Statistics, was carried out on pretest and posttest data, as a prerequisite for hypothesis testing [18]. Hypothesis testing uses an independent-samples t-test to compare the means of two independent groups, namely the experimental and control classes. with the help of SPSS. The basis of the decision if the significance value (Sig. 2-tailed) $<0.05$, then $H_0$ is rejected and $H_a$ is accepted, whereas if the significance value $>0.05$, then $H_0$ is accepted and $H_a$ is rejected [19]. Supporting data are calculated using N-Gain to show the pretest and posttest values, which indicate a significant effect in the experimental and control classes.

## Results and Discussion

This research is designed to help students achieve scientific literacy competencies, where students can understand scientific literacy indicators according to the International Student Assessment Program according to the indicators, namely: (1) explaining phenomena scientifically, (2) designing and conducting scientific investigations, and (3) interpreting scientific data and evidence [20]. Students' scientific literacy results are shown in Figure 1.

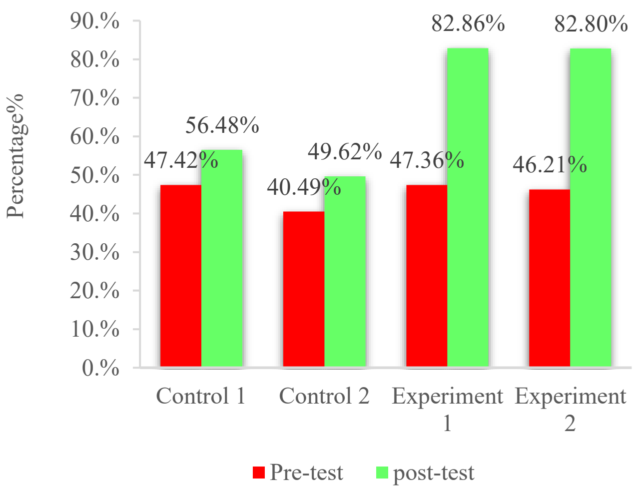


**Figure 1.** Pretest-Posttest Results

Based on the research data in Figure 2, all classes showed an increase in scientific literacy from pre-test to post-test. In the pre-test phase, the average score was 47.42% for control class 1, 40.49% for control class 2, 47.36% for experimental class 1, and 46.21% for experimental class 2. After the learning process was implemented, all classes showed improvement on the post-test. In control class 1, the average score increased from 47.42% to 56.48%, while in control class 2, it increased from 40.49% to 49.62%. A much greater increase occurred in the experimental classes. Experimental Class 1 saw an increase from 47.36% to 82.86%, while Experimental Class 2 increased from 46.21% to 82.80%.

The greater improvement in the experimental class indicates that using virtual laboratory-based learning media with PhET Simulations is more effective in improving students' scientific literacy than the control class. In other words, the Virtual Laboratory helps students understand the abstract concepts of temperature and heat through more realistic visualizations. Furthermore, the use of PhET encourages students to explore, observe changes in variables, interpret data, and draw conclusions based on scientific evidence [21].

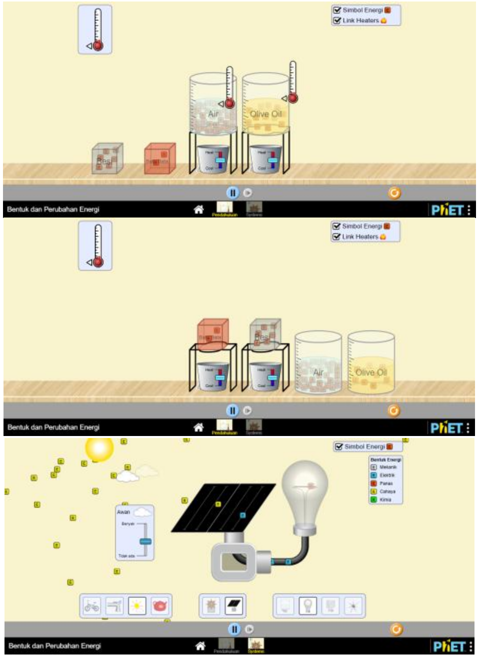


**Figure 2.** Temperature and Heat Learning Activities Through the PhET Virtual Laboratory

Thus, although all classes improved in scientific literacy, the experimental class showed greater gains than the control class. This indicates that implementing virtual laboratories in science learning has a positive impact on students' scientific literacy. Although all classes showed an increase in scientific literacy, the experimental class showed a larger increase than the control class.

Using the PhET virtual laboratory on temperature and heat helps improve students' scientific literacy (Figure 2). Through interactive simulations, students can directly observe the phenomena of heat transfer, temperature changes, and energy transformations without the limitations of physical laboratory equipment. The exploration, observation, and analysis activities carried out while using PhET help students understand scientific concepts more deeply, interpret experimental data, and connect theories to phenomena in everyday life. Thus, the PhET virtual laboratory not only improves understanding of the concepts of temperature and heat but also develops scientific literacy skills, including explaining scientific phenomena, evaluating scientific evidence, and making data-driven decisions.

### Data Normality Test

Data normality was tested using the Shapiro-Wilk test with IBM SPSS Statistics. The basis for decision-making is that if the significance value (Sig.) is greater than 0.05, the data is declared normally distributed. Meanwhile, if the significance value is less than 0.05, the data is declared non-normally distributed[22].

**Table 1.** Normality Test Result

| Data | Class | Statistics | df | Sig, | Information |
|---|---|---|---|---|---|
| Pretest | Control 1 | 0.97 | 26 | 0.82 | Normally Distributed |
| | Control 2 | 0.95 | 26 | 0.23 | Normally Distributed |
| | Experiment 1 | 0.97 | 26 | 0.76 | Normally Distributed |
| | Experiment 2 | 0.96 | 26 | 0.51 | Normally Distributed |
| Posttest | Control 1 | 0.97 | 26 | 0.24 | Normally Distributed |
| | Control 2 | 0.95 | 26 | 0.06 | Normally Distributed |
| | Experiment 1 | 0.97 | 26 | 0.12 | Normally Distributed |
| | Experiment 2 | 0.96 | 26 | 0.27 | Normally Distributed |

Based on the results of the normality test, the significance value (Sig.) for the pretest and posttest data from all classes is above the significance level $\alpha = 0.05$. In the pretest data, the significance values are 0.82 for Control Class 1, 0.23 for Control Class 2, 0.76 for Experimental Class 1, and 0.51 for Experimental Class 2. Meanwhile, in the posttest data, the significance values are 0.24 for Control Class 1, 0.06 for Control Class 2, 0.12 for Experimental Class 1, and 0.27 for Experimental Class 2. According to the testing criteria, data is considered normal if the significance value is greater than 0.05. It can be said that all pretest and posttest data from both the control and experimental classes are normally distributed and suitable for parametric statistical analysis. These results are consistent with statistical testing procedures in educational research, indicating that parametric analysis, such as the independent sample t-test, can be applied appropriately to evaluate differences between groups [23].

### Data Homogeneity Test

The homogeneity test uses IBM SPSS Statistics with the Levene Test at a significance level of 0.05 to determine whether the data variances in each research group (control and experimental) are similar (homogeneous).

**Table 2.** Homogeneity Test Results

| Test | Levene Statistics | Df1 | Df2 | Sig. | Status |
|---|---|---|---|---|---|
| Pre | 1.41 | 3 | 100 | .935 | Homogeneous |
| Post | .930 | 3 | 100 | .429 | Homogeneous |

Based on the Levene test results, the significance values for the pretest and posttest were 0.935 and 0.429, respectively. Both values are greater than the 0.05 significance level, indicating that there is no significant difference in variance between the control and experimental classes, both in the pretest and posttest data. Thus, it meets the requirements for further parametric statistical analysis, such as the independent sample t-test.

**Data Hypothesis Testing**

Hypothesis testing used an independent-samples t-test to compare students' scientific literacy between the experimental and control classes. The experimental class received the treatment, while the control class received no virtual laboratory treatment. The test results are shown in the following table [24].

Based on the results of the independent sample t-test, the significance value of the Levene test in SMP Negeri 1 Suwawa was 0.284, and in SMP Negeri 2 Suwawa was 0.616. Both values are greater than 0.05, so the data is declared homogeneous. In addition, the significance value (Sig. 2-tailed) in both schools is 0.000 (<0.05), indicating a significant difference between the experimental and control classes. Therefore, $H_0$ is rejected and $H_1$ is accepted, where interactive learning media based on virtual laboratories are proven to have a significant effect on students' scientific literacy. This finding is consistent with previous studies that reported that virtual laboratories and PhET-based learning can effectively improve students' scientific literacy, conceptual understanding, and scientific reasoning skills [25].

**Table 3.** Hypothesis Test Results

| Class | Levene Sig. | t-count | df | Sig.(2-failed) | Information |
|---|---|---|---|---|---|
| Control 1 vs Experiment 1 | 0.284 | -7.077 | 50 | 0.000 | $H_0$ rejected |
| Control 2 vs Experiment 2 | 0.616 | -10.530 | 50 | 0.000 | $H_0$ rejected |

**N-Gain Test**

The N-Gain test was used to determine the effectiveness of learning in improving students' scientific literacy. The N-Gain analysis in the study used the normalized average gain for each class: control class 1, control class 2, experimental class 1, and experimental class 2[26].

**Table 4.** N-Gain Test Results

| Class | N-Gain | Criteria |
|---|---|---|
| Control 1 | 0.17 | Low |
| Control 1 | 0.14 | Low |
| Experiment 1 | 0.63 | Currently |
| Experiment 2 | 0.63 | Currently |

Based on the table, N-Gain shows the average in Control Class 1 is 0.17 and in Control Class 2 is 0.14, both of which are categorized as low. Meanwhile, Experimental Class 1 and Experimental Class 2 each obtained a score of 0.63, which is categorized as medium. It is stated that the increase in scientific literacy in the experimental class is higher than in the control class. Therefore, interactive learning through virtual laboratories is more effective at improving students' scientific literacy. This result is supported by previous research, which states that interactive virtual laboratories can improve investigation skills and scientific literacy [27].

## Conclusion

Based on the research results, the conclusion is that the use of interactive learning media based on virtual laboratories significantly improves students' scientific literacy in the material on temperature and heat at SMP Negeri 1 Suwawa and SMP Negeri 2 Suwawa. This is supported by the results of the independent-samples t-test, which indicate that $H_0$ is rejected and $H_1$ is accepted. Then, strengthened by the N-Gain analysis of Experimental Class 1 and Experimental Class 2, each obtained an N-Gain value of 0.63 in the medium category, while Control Class 1 and Control Class 2 obtained a value of 0.17 and 0.14 in the low category. Therefore, teachers are advised to integrate virtual laboratory activities into science learning, especially for abstract topics that require visualization and experimentation, such as temperature and heat. This research contributes to the development of digital-based science learning. Further studies are recommended to investigate the implementation of virtual laboratory learning on science topics involving a larger research population.

**Author's Contribution**

P. Tantalama: conceptualization, original paper preparation, Methodology. T. Abdjul: curation, writing the original draft. Nurhayati: methodology and validation. H. Odja: writing, review and editing; M. Yusuf: formal analysis, methodology.

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## References

[1] H. J. Banda and J. Nzabahimana, "The Impact of Physics Education Technology (PhET) Interactive Simulation-Based Learning on Motivation and Academic Achievement Among Malawian Physics Students," *J. Sci. Educ. Technol.*, vol. 32, no. 1, pp. 127–141, 2023, doi: 10.1007/s10956-022-10010-3.

[2] S. Wati and N. Nurhasannah, "Penguatan Kompetensi Guru Dalam Menghadapi Era Digital," *J. Rev. Pendidik. Dasar J. Kaji. Pendidik. dan Has. Penelit.*, vol. 10, no. 2, pp. 149–155, 2024, doi: 10.26740/jrpd.v10n2.p149-155.

[3] D. W. Maharani, "Peran Keterampilan Laboratorium Merancang Pratikum untuk Menumbuhkan Literasi Sains yang Efektif dalam Pembelajaran IPA," *Semin. Nas. IPA XV*, pp. 544–551, 2025.

[4] G. N. Ayu, C. A. Putri, A. R. Riyanto, and I. Koto, "The Scientific Literacy Competence of Students in Indonesia and Mexico Based on PISA 2022: An International Comparative Study," *TOFEDU Futur. Educ. J.*, vol. 4, no. 5, pp. 1033–1038, 2025, doi:

10.61445/tofedu.v4i5.525.
[5] Rosmiati, “pengaruh model problem based learning berbasis tutor teman sebaya terhadap literasi sains murid: kajian literatur,” *J. Penelit. Ilmu Pendidik.*, vol. 8, no. 1, pp. 1–153, 2024.
[6] F. Yusmar and R. E. Fadilah, “Analisis Rendahnya Literasi Sains Peserta Didik Indonesia: Hasil Pisa Dan Faktor Penyebab,” *LENSA (Lentera Sains) J. Pendidik. IPA*, vol. 13, no. 1, pp. 11–19, 2023, doi: 10.24929/lensa.v13i1.283.
[7] D. I. Sdn and T. Indah, “Penggunaan Laboratorium Virtual Dan Praktikum Ipa,” *J. ABDIMAS Ilm. CITRA BAKTI*, vol. 6, 2025.
[8] Z. J. Hadi, S. Rahayu, A. Busyairi, and I. W. Gunada, “Pengembangan Perangkat Pembelajaran Model Inquiry Training Berbantuan Media PhET untuk Meningkatkan Pemahaman Konsep Fisika Peserta Didik,” *J. Pendidikan, Sains, Geol. dan Geofis. (GeoScienceEd Journal)*, vol. 6, no. 1, pp. 580–583, 2025, doi: 10.29303/goescienceed.v6i1.544.
[9] N. P. Naki, T. Abdjul, N. Nurhayati, A. H. Odja, M. Yusuf, and C. S. Payu, “The Effect of Implementing Interactive Learning Media Based on Virtual Laboratory on Student Learning Outcomes in Force Topic,” *J. Pijar Mipa*, vol. 20, no. 1, pp. 148–153, 2025, doi: 10.29303/jpm.v20i1.8403.
[10] T. Abdjul, A. H. Odja, and Nurhayati, “Effectiveness of Virtual Laboratory-Based Interactive Learning Media Through a Differentiated Approach to Students’ Scientific Literacy,” *J. Penelit. Pendidik. IPA*, vol. 10, no. 11, pp. 9838–9838, 2024, doi: 10.29303/jppipa.v10i11.9253.
[11] N. F. Amin and W. Sulistiyowati, “konsep umum populasi dan sampel dalam penelitian Nur,” *Buku Ajar Stat. Dasar*, vol. 14, no. 1, pp. 15–31, 2023, doi: 10.21070/2017/978-979-3401-73-7.
[12] I. Abraham and Y. Supriyati, “Desain Kuasi Eksperimen Dalam Pendidikan: Literatur Review,” *J. Ilm. Mandala Educ.*, vol. 8, no. 3, pp. 2476–2482, 2022, doi: 10.58258/jime.v8i3.3800.
[13] M. Mushofa, D. Hermina, and N. Huda, “Memahami Populasi dan Sampel: Pilar Utama dalam Penelitian Kuantitatif,” *J. Syntax Admiration*, vol. 5, no. 12, pp. 5937–5948, 2024, doi: 10.46799/jsa.v5i12.1992.
[14] M. Ahmad and S. Wilkins, “Purposive sampling in qualitative research: a framework for the entire journey,” *Qual. Quant.*, vol. 59, no. 2, pp. 1461–1479, 2025, doi: 10.1007/s11135-024-02022-5.
[15] A. Wulandari, “PhET Simulation : a qualitative descriptive study on argumentation,” *J. JARLITBANG Pendidik.*, vol. 10, no. 2, pp. 187–194, 2024.
[16] M. F. Ramadhan, R. A. Siroj, and M. W. Afgani, “Validitas and Reliabilitas,” *J. Educ.*, vol. 6, no. 2, pp. 10967–10975, 2024, doi: 10.31004/joe.v6i2.4885.
[17] J. E. Perjuangan, “pengaruh penggunaan augmented reality terhadap kemampuan literasi sains siswa pada materi sistem peredaran darah,” *J. Ilm. Pendidik. Dasar*, vol. 2, no. 2, pp. 138–153, 2021.
[18] A. Arbadilah, E. Juliyanto, and N. Dewantari, “Efektivitas Model Pembelajaran Inkuiri Terbimbing Berbantuan Powtoon untuk Meningkatkan Kemampuan Literasi Sains pada Materi Zat dan Perubahannya Effectiveness of the Powtoon-assisted Guided Inquiry Learning Model to Improve Science Literacy Skills on Mat,” *J. Pendidik. Mat. dan Sains,* vol. 13, no. 2, pp. 431–443, 2025.
[19] I. J. Nurjanah, T. Ruatini, and M. H. Arifin, “Pengaruh Model Pembelajaran Project Based Learning Pada Pembelajaran IPS Dalam Meningkatkan Keterampilan Literasi Finansial Siswa Kelas IV Sekolah Dasar,” *J. Ilmu Kependidikan*, vol. 21, no. 1, pp. 1–14, 2026, doi: 10.29408/edc.v21i1.31018.
[20] P. N. Putri, F. Rachmadiarti, T. Purnomo, and M. Satriawan, “Measuring Scientific Literacy of Students’ Through Environmental Issues Based on PISA 2025 Science Framework,” *J. Penelit. Pendidik. IPA*, vol. 11, no. 3, pp. 44–53, 2025, doi: 10.29303/jppipa.v11i3.10413.
[21] D. P. Kamilah, D. Sulisworo, and J. Firmansyah, “The Impact of PhET Simulations on Conceptual Understanding in High School Physics: Evidence from Indonesian Studies,” *J. Educ. Sci.*, vol. 9, no. 6, pp. 6229–6244, 2025.
[22] N. Polihito, T. Abdjul, N. E. Ntobuo, M. Yusuf, A. H. Odja, and N. Nurhayati, “Implementation of Interactive Learning Media Based on Virtual Laboratory on Student Science Literacy Skills,” *J. Pijar Mipa*, vol. 20, no. 4, pp. 681–686, 2025, doi: 10.29303/jpm.v20i4.9138.
[23] E. L. Bimawati Rumapea *et al.*, “Investigating the Use of Comic Strips Media on Developing Students’ Narrative Writing Skills: A Case Study in Language Teaching,” *AL-ISHLAH J. Pendidik.*, vol. 17, no. 2, pp. 2526–2536, 2025, doi: 10.35445/alishlah.v17i2.7345.
[24] R. Herak and L. Seran, “Efektivitas Pembelajaran Berbasis Masalah dalam Meningkatkan Keterampilan Proses Sains Siswa Sekolah Menengah Atas,” *J. Stud. Guru dan Pembelajaran*, vol. 8, no. 3, pp. 1805–1814, 2025, [Online]. Available: https://doi.org/10.30605/jsgp.8.3.2025.6983
[25] I Gede Yoga Danu Tirta, I Gede Astawan, and Ni Ketut Desia Tristiantari, “Project-Based Learning Assisted by Virtual Practicals with the PhET Application as an Effort to Improve Scientific Attitudes and Literacy,” *Indones. J. Instr.*, vol. 6, no. 2, pp. 449–461, 2025, doi: 10.23887/iji.v6i2.92518.
[26] M. Saputri, Lilis, “Desain Penelitian Quasi Eksperimen Dalam Penelitian Pendidikan : Kajian Pustaka,” *J. Serunai Mat.*, vol. 17, no. 2, pp. 78–79, 2025.
[27] D. R. Darman, N. Nurhasanah, L. Zakiah, and N. Fauziah, “Virtual Laboratory Science to Improve Students ’ Science Literacy Ability,” *J. Nat. Sci. Integr.*, vol. 9, no. 1, pp. 54–70, doi: 10.24014/jnsi.v9i1.37902.