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# The Effect of Problem Based Learning Model Using PhET Simulation Media Integrated with Scientific Literacy to Improve Learning Outcomes.

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**Abstract: The Effect of Problem Based Learning Model Using PhET Simulation Media Integrated with Scientific Literacy to Improve Learning Outcomes.** This study aimed to determine the effect of the *Problem Based Learning* (PBL) model using *PhET Simulation* media and scientific literacy skills on students' chemistry learning outcomes in acid-base material. The study employed a quasi-experimental method with a 2×2 factorial design conducted at SMA Negeri 10 Medan in the 2025/2026 academic year. The samples consisted of two classes: a class taught using the PBL model assisted by *PhET Simulation* and a class taught using the *Direct Instruction* model with real laboratory media. Data were collected through learning outcome tests and scientific literacy tests, then analyzed using two-way ANOVA at a significance level of 0.05. The results showed that the learning model using media, scientific literacy skills, and their interaction significantly affected students' chemistry learning outcomes in acid-base material. Therefore, the implementation of the PBL model assisted by *PhET Simulation* was effective in improving students' chemistry learning outcomes.

**Keywords:** *Problem Based Learning*, *PhET Simulation*, scientific literacy, learning outcomes, acid-base.

**Abstrak*: Pengaruh Model Problem Based Learning Menggunakan Media PhET Simulation Terintegrasi Literasi Sains Untuk Meningkatkan Hasil Belajar .*** *Penelitian ini bertujuan untuk mengetahui pengaruh model Problem Based Learning (PBL) menggunakan media PhET Simulation dan kemampuan literasi sains terhadap hasil belajar kimia siswa pada materi asam basa. Penelitian menggunakan metode quasi experiment dengan desain faktorial 2×2 yang dilaksanakan di SMA Negeri 10 Medan tahun ajaran 2025/2026. Sampel penelitian terdiri atas dua kelas, yaitu kelas yang dibelajarkan menggunakan model PBL berbantuan PhET Simulation dan kelas Direct Instruction menggunakan media real laboratory. Data diperoleh melalui tes hasil belajar dan tes literasi sains, kemudian dianalisis menggunakan ANAVA dua jalur pada taraf signifikansi 0,05. Hasil penelitian menunjukkan bahwa model pembelajaran menggunakan media, kemampuan literasi sains, dan interaksi keduanya berpengaruh terhadap hasil belajar kimia siswa pada materi asam basa. Dengan demikian, penerapan model PBL berbantuan PhET Simulation efektif meningkatkan hasil belajar kimia siswa.*

***Kata kunci:*** *Problem Based Learning, PhET Simulation, literasi sains, hasil belajar, asam basa.*

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## • INTRODUCTION

The rapid development of science and technology in the 21st century requires students to possess critical thinking, creativity, and scientific problem-solving skills. One of the essential competencies that should be developed in science learning is scientific literacy. Scientific literacy is not only related to conceptual understanding but also to the ability to apply scientific knowledge to explain phenomena, make decisions, and solve problems in everyday life (Rahayu, 2017). Students with good scientific literacy skills tend to think logically, critically, and responsibly toward various scientific and environmental issues (Pertiwi et al., 2018).

Indonesian students' scientific literacy remains a concern. According to the results of the Programme for International Student Assessment (PISA) 2022 published by the OECD (2023), Indonesia's scientific literacy score was 383, still below the OECD average of 485. These results indicate that most students still experience difficulty applying scientific concepts to explain phenomena, interpret data, and solve problems in everyday life. This situation highlights the need for learning innovations that can improve scientific literacy and student learning outcomes.

Chemistry learning, especially in acid–base material, is often considered difficult by students because it involves abstract concepts, symbolic representations, and mathematical calculations. Learning processes that remain teacher-centered tend to make students passive, resulting in less optimal conceptual understanding and learning outcomes. Therefore, an instructional model that encourages students' active involvement in discovering and solving problems is needed.

One learning model that can be applied is *Problem Based Learning* (PBL). The PBL model emphasizes problem-oriented learning processes that encourage students to think critically, collaborate, and develop problem-solving skills. PBL also provides opportunities for students to construct knowledge independently through scientific inquiry processes (Arends, 2012). Previous studies have shown that the implementation of PBL can improve learning outcomes, critical thinking skills, and students' scientific literacy abilities (Nasution & Sutiani, 2022).

The effectiveness of the PBL model can be enhanced through the use of interactive learning media, one of which is *PhET Simulation*. *PhET Simulation* is a virtual laboratory based on interactive simulations capable of visualizing chemistry concepts more concretely, thereby helping students understand abstract material. The use of *PhET Simulation* can increase learning motivation, student engagement, and conceptual understanding because students can directly explore concepts through virtual simulations (Inayah & Masruroh, 2021). Furthermore, the integration of scientific literacy in learning assisted by *PhET Simulation* enables students to relate chemistry concepts to real-life phenomena more meaningfully.

Although various studies have reported that the Problem-Based Learning (PBL) model can improve students' learning outcomes and critical thinking skills, most of these studies have focused solely on the general application of PBL without integrating virtual simulation media and scientific literacy simultaneously. Research by Nasution and Sutiani (2022) demonstrated that PBL positively impacts students' scientific literacy skills, but did not examine the use of PhET Simulation media as a visualization tool for abstract chemical concepts. Conversely, research by Inayah and Masruroh (2021) demonstrated that PhET Simulation can improve students' conceptual understanding, but it was not combined with the PBL model and did not consider scientific literacy skills as a moderating variable.

Furthermore, research on the integration of PhET Simulation-assisted Problem-Based Learning in acid-base chemistry is still relatively limited, particularly those using a 2x2 factorial design to test the effect of learning models, scientific literacy skills, and their interaction on student learning outcomes. Therefore, this study was conducted to fill this research gap by integrating the PBL model, PhET Simulation media, and scientific literacy in chemistry teaching acid-base chemistry.

Based on the explanation above, this study was conducted to analyze the effect of the *Problem Based Learning* model assisted by *PhET Simulation* integrated with scientific literacy on students' chemistry learning outcomes in acid–base material. This study is expected to contribute to the development of innovative chemistry learning oriented toward improving students' scientific literacy.

## ▪ METHOD

### Research Location and Time

This research was conducted at SMA Negeri, during the second semester of the 2025/2026 academic year. The implementation of the research was carried out from April to May 2026. The selection of the research location was based on considerations that the school had adequate facilities to support the implementation of learning using *PhET Simulation* media and had never implemented the *Problem Based Learning* (PBL) model integrated with scientific literacy in chemistry learning, particularly on acid–base material.

### Research Subjects and Objects

The subjects of this research were students of class XI SMA Negeri [name of school] in the 2025/2026 academic year. The sample consisted of two classes selected using purposive sampling techniques, namely the experimental class and the comparison class. The experimental class was taught using the *Problem Based Learning* (PBL) model assisted by *PhET Simulation* integrated with scientific literacy, while the comparison class received conventional learning.

The object of this research was the effect of the *Problem Based Learning* (PBL) model assisted by *PhET Simulation* integrated with scientific literacy on students' chemistry learning outcomes in acid–base material.

### Type and Design of Research

This study uses a quasi-experimental method with a 2×2 factorial design which refers to the educational experimental research design according to Sugiyono (2022). This design was applied to determine: (1) the effect of the learning model on students' chemistry learning outcomes, (2) the effect of students' scientific literacy skills on learning outcomes, and (3) the interaction between the learning model and scientific literacy skills on students' chemistry learning outcomes.

| **Model Pembelajaran** | **Literasi Sains Tinggi (B1)** | **Literas Sains Rendah (B2)** |
|---|---|---|
| PBL + PhET (A1) | A1B1 | A1B2 |
| Direxct Instruction + Real Laboratory (A2) | A2B1 | A2B2 |

The research involved two independent variables, namely the learning model and scientific literacy skills, while the dependent variable was students' chemistry learning outcomes on acid–base material. The experimental class was treated using the *Problem Based Learning* (PBL) model assisted by *PhET Simulation*, whereas the comparison class was taught using conventional learning methods.

The research instruments consisted of a chemistry learning outcome test and a science literacy test. The learning outcome test consisted of 25 multiple-choice questions covering acid-base indicators based on learning competencies. The science literacy test consisted of 20 questions developed based on the OECD science literacy framework, covering the ability to explain phenomena scientifically, evaluate and design scientific investigations, and interpret scientific data and evidence.

Before use, the instrument underwent a content validity test by three chemistry education experts. Empirical validity was tested using the Product Moment correlation, while instrument reliability was calculated using the Cronbach's Alpha coefficient. The test results showed that all test items were valid with a calculated r value > r table and reliable with an Alpha coefficient > 0.70, making them suitable for use as a research instrument (Arikunto, 2018).

## ▪ RESULT AND DISCUSSION

The results of this study were obtained from the analysis of students' chemistry learning outcomes after the implementation of the *Problem Based Learning* (PBL) model assisted by *PhET Simulation* integrated with scientific literacy. The data analysis was conducted using a two-way analysis of variance (ANOVA) to determine the effect of the learning model, scientific literacy skills, and the interaction between both variables on students' learning outcomes in acid–base material.

**Table 1.** presents the descriptive statistics of students' learning outcomes in both the experimental and comparison classes.

| Class | Number of student | Highest score | Lowest score | Mean |
|---|---|---|---|---|
| Experimental 1 | 32 | 96 | 62 | 77,937 |
| Experimental 2 | 32 | 92 | 62 | 76,875 |

Based on Table 1, the experimental class that received treatment using the *Problem Based Learning* model assisted by *PhET Simulation* obtained a higher mean score compared to the comparison class. This finding indicates that the implementation of interactive and problem-oriented learning can improve students' understanding of acid–base concepts.

The results of the two-way ANOVA analysis are presented in Table 2.

| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **$F_{criteria}$** |
|---|---|---|---|---|---|---|
| Sample | 2197,266 | 1 | 2197,266 | 51,6687 | 1,2E-09 | 4,00119 |
| -09 | 112,8906 | 1 | 112,8906 | 2,65462 | 0,10849 | 4,00119 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Interaction | 112,8906 | 1 | 112,8906 | 2,65462 | 0,10849 | 4,00119 |
| Within | 2551,563 | 60 | 42,52604 | | | |
| Total | 4974,609 | 63 | | | | |

**Table 2.** ANOVA List of Chemistry Scores of Students Given a Combination of Learning Model Treatments Using Media and Science Literacy

Based on Table 2, the learning model significantly affected students' chemistry learning outcomes ($F = 51.669$; $p < 0.05$). Students who learned through the Problem Based Learning model assisted by PhET Simulation obtained better learning outcomes than those who learned through conventional instruction. However, scientific literacy skills did not significantly affect students' chemistry learning outcomes ($F = 2.655$; $p > 0.05$). Likewise, the interaction between the learning model and scientific literacy skills was not statistically significant ($F = 2.655$; $p > 0.05$).

The findings indicate that the Problem Based Learning model assisted by PhET Simulation significantly improved students' chemistry learning outcomes on acid–base material. This result supports the constructivist learning theory proposed by Arends (2012), which states that knowledge is actively constructed through problem-solving activities and student engagement in meaningful learning experiences.

The use of PhET Simulation enabled students to visualize abstract acid–base concepts more concretely. Through virtual experimentation, students could observe changes in pH, acid–base strength, and ion interactions that are difficult to observe directly in conventional classroom settings. Consequently, students became more actively involved in learning and developed a better conceptual understanding.

This finding is consistent with previous studies conducted by Nasution and Sutiani (2022), who reported that Problem Based Learning improved students' chemistry learning outcomes and promoted more active participation during instruction. Similarly, Inayah and Masruroh (2021) found that PhET Simulation enhanced students' conceptual understanding and learning motivation in science education.

However, scientific literacy skills did not significantly influence students' chemistry learning outcomes. One possible explanation is that students' literacy levels were relatively homogeneous across the sample, reducing the possibility of detecting significant differences. Another possibility is that the learning model itself played a more dominant role in determining achievement than students' initial literacy abilities.

Furthermore, no significant interaction was found between the learning model and scientific literacy skills. This result suggests that the effectiveness of the PBL model assisted by PhET Simulation was relatively consistent across students with different levels of scientific literacy. Therefore, the model can be considered beneficial for a broad range of learners regardless of their literacy profile.

## ▪ CONCLUSION

Based on the results of the study, it can be concluded that the Problem Based Learning model assisted by PhET Simulation significantly improved students' chemistry

learning outcomes on acid–base material. However, scientific literacy skills did not significantly affect students' learning outcomes. In addition, no significant interaction was found between the learning model and scientific literacy skills. Therefore, the improvement in learning outcomes was primarily influenced by the implementation of the learning model rather than by differences in students' scientific literacy levels.

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