



## Implementation of PhET Media in the Discovery Learning Model towards Student Learning Outcomes on Reaction Equations Material

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**Abstract: Implementation of PhET Media in the Discovery Learning Model towards Student Learning Outcomes in the Reaction Equations Material.** This study aims to determine the significant differences in student learning outcomes before and after using PhET media in the discovery learning model on reaction equations material. The population in this study were students of class X at MA Muhammadiyah Limbung which were divided into two class. The research sample were 22 students of class X.B selected using simple random sampling MA Muhammadiyah Limbung. The instruments used were pre-test and post-test with 20 questions. The research design used a one-group pre-test and post-test. This study was conducted in one meeting and observed by one observer. Normality tests indicated that the data obtained were not normally distributed, so testing was continued with non-parametric statistics, namely the Wilcoxon Signed Rank Test conducted using SPSS, and additional analysis, namely the N Gain Test. The results showed that PhET learning media was effective in improving student learning outcomes with a Sig.value of  $0.000 < 0.05$  and N-gain percentage 79.09%.

**Keywords:** *Discovery Learning, PhET, and Reaction Equation.*

**Abstrak: Penerapan Media PhET dalam Model Discovery Learning terhadap Hasil Belajar Peserta Didik pada Materi Persamaan Reaksi..** Penelitian ini bertujuan untuk mengetahui perbedaan signifikan hasil belajar siswa sebelum dan sesudah penggunaan media PhET dalam model discovery learning pada materi persamaan reaksi. Populasi dalam penelitian ini adalah peserta didik kelas X di MA Muhammadiyah Limbung yang terdiri dari dua kelas. Sampel penelitian adalah 22 siswa kelas X.B yang dipilih menggunakan simple random sampling di MA Muhammadiyah Limbung. Instrumen yang digunakan adalah pre-test dan post-test dengan 20 pertanyaan. Desain penelitian menggunakan one-group pre-test and post-test. Penelitian ini dilakukan dalam satu pertemuan dan diamati oleh satu pengamat. Uji normalitas menunjukkan bahwa data yang diperoleh tidak terdistribusi normal, sehingga pengujian dilanjutkan dengan statistik non-parametrik, yaitu Wilcoxon Signed Rank Test yang dilakukan menggunakan SPSS, dan analisis tambahan, yaitu Uji N-gain. Hasil penelitian menunjukkan bahwa media pembelajaran PhET efektif dalam meningkatkan hasil belajar siswa dengan nilai Sig. sebesar  $0,000 < 0,05$  dan N-gain sebesar 79,09%.

**Kata kunci:** *Discovery Learning, PhET, dan Persamaan Reaksi.*

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## ▪ INTRODUCTION

The advancement of science and technology requires an enhancement in educational standards. Education serves as the foundation for all advancements and improvements in quality, as it enables people to fully unlock their capabilities, both personally and as part of the community (Talaohu, 2022). Chemistry is the science that studies matter, its properties, changes, and the energy that accompanies these changes, including the energy released and absorbed (Sulakhudin, 2019). One topic in chemistry that still requires attention is reaction equations (Seliwati, 2021). A chemical reaction equation is an equation that shows the process of a change in matter that produces a new substance by stating the chemical formula, reaction coefficients, state of matter, indices, and reaction arrows that separate reactants and products (Lubis, 2026). In terms of content, reaction equations are among the topics that require students' conceptual understanding at three representative levels: macroscopic, submicroscopic, and symbolic.

Based on observations at MA Muhammadiyah Limbung, it was found that learning is still conventional, utilizing learning media such as printed textbooks and PowerPoint presentations. The learning implemented in this school still requires more attention to adapt to the characteristics of students in the current century. Generation Z is the generation currently attending school. One of their prominent characteristics is their familiarity with the intelligent use of technology (Prasetya *et al.*, 2021). Technology based learning media tends to be more engaging and enjoyable for students who are already familiar with using gadgets and digital devices (Sawitri *et al.*, 2024).

In today's digital era, advances in information and communication technology have increasingly developed. Numerous technology-enabled learning media, such as interactive learning videos, e-modules, e-learning platforms, and mobile applications, have emerged, all used to improve the quality of learning (Deno *et al.*, 2025). Teacher as a educators, the skill of selecting and integrating appropriate learning media is key to successfully delivering learning materials in an engaging and efficient manner (Septiana, 2024).

One learning medium that can be used for chemical equations is PhET. Utilizing media such as PhET Interactive Simulations, developed by the University of Colorado Boudler, can provide interactive visualizations of abstract and microscopic chemical concepts (Ulhaq *et al.*, 2023). Several studies have shown that PhET media has a positive and effective influence on increasing student learning engagement and learning outcomes. Research conducted by Satriawan (2025) demonstrated a significant increase in learning engagement through the use of interactive PhET media on acid-base topics. This media encourages students to ask questions, experiment, and discuss. Phet media can improve student learning outcomes through interactive simulations on acid-base material (Sihombing & Marini, 2026). Another study by Prastika *et al.* (2024) demonstrated that PhET, an artificial intelligence based media, has proven effective in developing students' thinking skills and abilities, such as identifying problems, evaluating, drawing conclusions, and expressing opinions.

One 21st-century learning model that can improve student motivation and learning outcomes is the discovery learning model. Discovery learning not only enhances conceptual understanding but also encourages students to take responsibility for their learning process, making it suitable for integration with PhET media (Hutasuhut *et al.*, 2025). Learning outcomes are the abilities students acquire through learning activities

and can be used as a measure of the success of the learning process (Arifin & Rini, 2021). The factors influencing learning outcomes are divided into two categories: internal and external (Mangangantung, 2023). Internal factors originate from within the student and can influence individual learning outcomes. Internal factors include physiological and psychological factors such as student interest, motivation, and talent. External factors are external factors that can influence students' learning processes, such as the school environment, family, as well as instrumental factors (Zulqarnain et al., 2022)

Based on the background description, a novelty was found for in previous research that had not yet been conducted on the implementation of PhET in the topic of reaction equations. Therefore, the researcher was interested in conducting research related to the implementation of PhET in the discovery learning model for reaction equations. This study aims to determine significant differences in student learning outcomes before and after using PhET media in the discovery learning model for reaction equations. This learning media is expected to be effective in improving student learning outcomes.

## ■ METHOD

This type of research is a pre-experimental study using a one-group pre-test and post-test design. A one-group pre-test and post-test design is a research design that takes one measurement at the beginning (pre-test) before the treatment is administered, and then another measurement (post-test) (Siregar & Ali H., 2021). This design allows researchers to compare student conditions before and after treatment through the administration of pre-tests and post-tests, so that the effects of the treatment can be more clearly observed. With the initial measurement (pre-test), researchers can determine students' initial abilities, while the final measurement (post-test) is used to see improvements in learning outcomes after learning with PhET media. The design can be seen in Table 1.

**Table 1.** Research Design

| Pre-test | Treatment | Post-test |
|----------|-----------|-----------|
| O1       | X         | O2        |

(Noor, 2011)

This research was conducted at a school located on H. Patolla Sibali Street, Gowa, South Sulawesi in April of the even semester of the 2025/2026 academic year. The population was 10th grade students at MA Muhammadiyah Limbung, consisting of two classes X.A and X.B. The sample was selected using simple random sampling, with 22 students from X.B selected. Learning was carried out for 1 meeting consisting of 3x45 minutes lesson hours with discovery learning model. The steps of the discovery learning model consist of stimulation, problem statement, data collection, data processing, verification, and generalization (Syamsidah et al., 2023)

Data collection involved pre-test and post-test learning outcomes. The research instrument used was a learning outcomes test containing 20 multiple choice questions on chemical reaction equations. The question indicators consist of 4 learning objectives divided into 20 question numbers. The first learning objective is to explain reactants and products (4 numbers), differentiate coefficients, indices, and states of matter (5 numbers), create reaction equations (4), and balance reaction equations (7 numbers).

Students were deemed to have mastered the material after completing the post-test and achieving a score above the minimum standard of 75 (KKTP). The results were then

analyzed using the Wilcoxon Signed Rank Test and the N-Gain score using SPSS Statistic Version 27. If the students' scores after the learning process were higher than before, it could be concluded that the PhET media used in learning, especially the chemical reaction equation material, was effective.

## ■ RESULT AND DISCUSSION

The research was conducted in one meeting and used only one class as a sample without using a comparison class. The number of students in one class was 22 people and were divided into 4 groups to conduct discussions and work on the distributed Student Worksheets (LKPD). At the beginning of the lesson, students were given a pre-test to determine their initial understanding of the concept of reaction equations. Entering the learning with the Discovery Learning model at the stimulus stage, the teacher provided a simulation of reaction balancing using PhET. In the verification stage, students were also asked to balance reactions using PhET media. Students are given the opportunity to changing the amount of reactants, observing the results of reactions, and comparing various conditions available in the simulation. These activities foster curiosity and increase learning motivation because they can gain a more engaging learning experience than conventional learning. Students showed a very enthusiastic attitude in using this media.

PhET media provides a safe and interactive learning environment, where students can engage in trial and error without fear of making mistakes (Harmita, 2025). The instant feedback feature in this simulation allows students to independently develop their understanding (Dendodi, 2025). This enhances their independence, which positively impacts memory and learning outcomes because the knowledge construction process occurs actively, rather than passively.



**Figure 1.** PhET Media in Reaction Equations

At the end of the lesson, students were given a final test or post-test. The purpose of the post-test was to determine students' understanding after implementing PhET learning. The post-test questions were structured based on the learning objectives and consisted of 20 multiple-choice questions. The students' learning outcomes in the pre-test and post-test can be seen in Table 2.

**Table 2.** Student Learning Outcomes in Pre-test and Post-test

| Learning Outcomes Value | <i>Pre-test (student)</i> | <i>Post-test (student)</i> |
|-------------------------|---------------------------|----------------------------|
| 10                      | -                         | -                          |

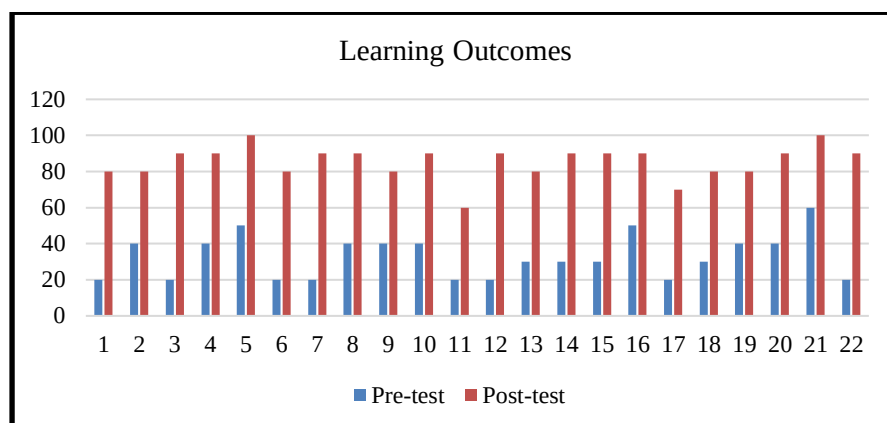
| <b>Learning Outcomes Value</b> | <b>Pre-test (student)</b> | <b>Post-test (student)</b> |
|--------------------------------|---------------------------|----------------------------|
| 20                             | 8                         | -                          |
| 30                             | 4                         | -                          |
| 40                             | 7                         | -                          |
| 50                             | 2                         | -                          |
| 60                             | 1                         | 1                          |
| 70                             | -                         | 1                          |
| 80                             | -                         | 7                          |
| 90                             | -                         | 11                         |
| 100                            | -                         | 2                          |

In the pre-test, most of the scores obtained by students were between 20 and 40 with an average score of 32,73, indicating that their initial understanding of reaction equations was still relatively low. The highest score was reached 60, while the lowest score was 20. Through the variation of student scores, it can be seen that none of the scores obtained have reached the completeness standard of 75. This indicates that students' initial understanding is still limited and requires better learning to improve their conceptual understanding. A descriptive interpretation of student learning outcomes can be seen in Table 3.

**Table 3.** Statistic Descriptive

| <b>Statistic Descriptive</b> | <b>Pre-test</b> | <b>Post-test</b> |
|------------------------------|-----------------|------------------|
| N                            | 22              | 22               |
| Minimum Statistic            | 20              | 60               |
| Maximum Statistic            | 60              | 100              |
| Mean                         | 32,73           | 85,45            |
| Std. Deviation               | 12              | 9                |
| Variance                     | 144,589         | 83,12            |

The low average pre-test score indicates that students still have difficulty understanding the basic concepts of equations and reaction balancing with conventional learning methods used so far. These results demonstrate the importance of using learning media that are appropriate to the characteristics of students, such as PhET, which is able to visualize concepts more concretely, thereby facilitating the construction of student understanding (Ramadhani et al., 2025). Through the implementation of this media, it is expected to improve student learning outcomes which will later be measured through a post-test.

**Graph 1.** Student Learning Outcomes

Based on the post-test results, the majority of students obtained scores between 80 and 90, with an average score of 85,45. This indicates that there has been a change and improvement in student understanding. Almost all students obtained scores above the completion standard, indicating that the implementation of PhET in this reaction equation material is effective in helping students understand concepts that were previously considered difficult. The post-test results indicate that the learning carried out successfully improved student understanding compared to conventional learning methods such as lectures (Kelvin, 2025).

Students failed to complete the pre-test due to their lack of understanding of the reaction equations material. However, after completing the PhET learning model and completing the post-test, 20 students achieved scores above the standard and were deemed to have completed the test. This indicates that the PhET model is effective in improving student learning outcomes.

**Figure 2.** Documentation of Post-test

The test then proceeded to inferential statistics to fully describe the data obtained. First, a normality test was conducted to determine whether the sample was normally distributed. Based on the SPSS normality test, the normality value was  $0.006 < 0.05$ , indicating that the sample was not normally distributed. Therefore, the test continued with non-parametric statistics, namely the Wilcoxon Signed Rank Test. The test results showed a Sig.  $0.000 < 0.05$ , indicating a significant difference before and after the PhET model was implemented in the discovery learning model for reaction equations.

**Figure 3.** Significance Value

Additional analysis, including the N-Gain test, was conducted to determine the extent of improvement in student learning outcomes and to assess the effectiveness of the PhET model used in this study. Based on the test results, the average N-Gain value was 0.7909, which is in the High category. Therefore, as a percentage, the N-Gain was 79.09%, indicating that the PhET media used in the Discovery Learning model was highly effective in teaching reaction equations.

This is supported by the theory that two factors influence learning outcomes: internal factors, including physiological and psychological factors, and external factors, including environmental and instrumental factors (Zulqarnain et al., 2022). PhET media

| Test Statistics <sup>a</sup>  |                      |
|-------------------------------|----------------------|
|                               | post-test - pre-test |
| Z                             | -4.145 <sup>b</sup>  |
| Asymp. Sig. (2-tailed)        | .000                 |
| a. Wilcoxon Signed Ranks Test |                      |
| b. Based on negative ranks    |                      |

falls under this external factor, namely instrumental factors originating from outside. This media can facilitate student mastery of the material compared to conventional learning methods. Most students responded positively to the benefits and ease of use of this simulation (Maanari et al., 2025). The use of PhET in learning can increase student learning motivation, as evidenced by their active participation during the learning process, which in turn impacts student learning outcomes (Fauziah et al., 2024).

Constructivist learning theory emphasizes the importance of student activeness in building conceptual understanding, and PhET media provides an effective visual interactive environment to support this process (Pratami, 2024). PhET provides an interactive learning environment so that students not only receive information but also explore and discover concepts themselves (Romadoni et al., 2025). In the Discovery Learning model, students are expected to construct their own knowledge through a process of discovery. PhET media supports this process by providing a learning environment that allows students to explore various phenomena independently.

Through simulations, students can test hypotheses, discover patterns, and connect observations to the concepts being studied. In the case of reaction equations, students can conclude that the number of atoms before and after a reaction must be the same based on

their own exploration. Knowledge gained through direct experience tends to be more meaningful and lasting than knowledge acquired solely through teacher explanations.

Other research shows that guided inquiry-based PhET media has a positive impact on student learning outcomes. This improves students' critical thinking, analytical skills, and responsibility (Riyanti et al., 2025). This media is able to bridge abstract theory and concrete experiences, thereby strengthening student-centered learning and developing students' conceptual understanding. The integration of PhET in learning can improve student learning outcomes, student activity, and student responses in chemistry learning (Ilmi & Achmad, 2020). However, because the study was conducted in only one meeting, the improvements that occurred reflect more of a short-term understanding. Therefore, further research is needed to examine the effects of PhET use over a longer period.

## ■ CONCLUSION

Based on the analysis and discussion, it can be concluded that the learning outcomes of students before learning are relatively low and experience a very significant increase after learning. The test results show a Sig.0.000 <0.05 value with an N-gain value of 79.09% which indicates that there is a significant difference before and after being given the application of PhET media in the discovery learning model in the reaction equation material. An important finding of this study is the reduction in student errors in balancing reactions after learning using PhET. Teachers can use PhET as an alternative learning medium to help explain abstract chemistry material, particularly reaction equations. The use of PhET combined with the Discovery Learning model provides students with the opportunity to independently discover and construct concepts about reaction equations through exploration and discovery.

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