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THE EFFECT OF DISCOVERY LEARNING ASSISTED BY PHET SIMULATION MEDIA ON STUDENTS' MATHEMATICS LEARNING OUTCOMES IN EQUIVALENT FRACTION MATERIAL AT SMP NEGERI 2 PADANGSIDIMPUAN

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ABSTRACT

Mathematics learning requires instructional approaches that promote students' active participation and meaningful conceptual understanding. However, many junior secondary school students experience difficulties in learning equivalent fractions because the concepts are abstract and classroom instruction is often dominated by teacher-centered approaches with limited use of interactive learning media. This study aimed to examine the effect of the Discovery Learning model assisted by PhET Interactive Simulations on students' mathematics learning outcomes in equivalent fraction material. The study employed a quantitative approach using a quasi-experimental pretest–posttest control group design. Sixty seventh-grade students from SMP Negeri 2 Padangsidimpuan participated in the study and were divided into an experimental group and a control group. Data were collected using a validated mathematics achievement test and analyzed through descriptive statistics, the Kolmogorov–Smirnov normality test, Levene's homogeneity test, an Independent Samples *t*-test, N-Gain analysis, and the coefficient of determination using IBM SPSS Statistics. The results revealed that students who learned through Discovery Learning assisted by PhET Interactive Simulations achieved significantly higher mathematics learning outcomes than those who received conventional classroom instruction ($p < 0.05$). The experimental group also demonstrated greater learning improvement, as indicated by a higher N-Gain score, while the instructional treatment contributed 39.3% of the variance in students' learning outcomes. These findings indicate that integrating Discovery Learning with PhET Interactive Simulations provides an effective student-centered learning environment that enhances conceptual understanding and improves mathematics learning outcomes. Therefore, this instructional approach can be recommended as an alternative strategy for teaching equivalent fractions at the junior secondary school level.

Keywords: Discovery Learning, PhET Interactive Simulations, Mathematics Learning Outcomes, Equivalent Fractions, Quasi-Experimental Study

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PRELIMINARY

Mathematics is a fundamental discipline that plays a significant role in developing students' logical reasoning, critical thinking, communication, and problem-solving

abilities. Through mathematics, learners acquire the capacity to analyze information systematically, make logical decisions, and solve problems encountered in both academic and everyday contexts. Consequently, mathematics education is expected not only to improve students' computational skills but also to develop conceptual understanding and higher-order thinking skills necessary for lifelong learning (NCTM, 2020; OECD, 2023).

Despite its importance, mathematics remains one of the most challenging subjects for many junior secondary school students. One mathematical topic that frequently causes learning difficulties is equivalent fractions because the concept requires students to understand proportional relationships rather than simply perform procedural calculations. In many classrooms, students tend to memorize algorithms without understanding why different fractions can represent the same quantity. This limited conceptual understanding often leads to misconceptions, errors in solving fraction problems, and difficulties in learning subsequent mathematical topics such as ratio, proportion, algebra, and probability. Consequently, students' mathematics achievement and problem-solving abilities remain relatively low (OECD, 2023; Wijaya et al., 2021).

These learning difficulties are closely related to the instructional approaches commonly implemented in mathematics classrooms. Conventional teaching practices are generally dominated by teacher explanations and textbook exercises, providing limited opportunities for students to actively explore mathematical concepts. Such teacher-centered instruction often encourages passive learning and memorization instead of meaningful conceptual construction. As a result, students experience difficulties in visualizing abstract mathematical concepts and transferring their knowledge to unfamiliar situations (Mayer, 2004; NCTM, 2020).

To overcome these challenges, mathematics teachers are expected to implement innovative instructional models that actively involve students in constructing their own understanding. One instructional approach that supports this objective is Discovery Learning. Based on Bruner's constructivist learning theory, Discovery Learning encourages students to identify problems, collect information, analyze evidence, verify findings, and formulate conclusions independently. Through these inquiry-oriented learning activities, students are expected to develop deeper conceptual understanding, stronger reasoning skills, and greater learning independence (Bruner, 1961; Fitriani & Prahmana, 2021).

The rapid advancement of educational technology has also provided opportunities to enrich mathematics instruction through interactive digital learning media. One of the most widely used educational technologies is **PhET Interactive Simulations**, developed

by the University of Colorado Boulder. PhET provides dynamic and interactive visualizations that enable students to manipulate mathematical objects, observe relationships among concepts, receive immediate feedback, and conduct virtual explorations that are difficult to achieve through conventional instruction. Previous studies have demonstrated that interactive simulations improve students' conceptual understanding, learning motivation, engagement, and academic achievement because abstract mathematical concepts become more concrete and meaningful (Finkelstein et al., 2005; Perkins et al., 2006; Jeno et al., 2019).

Several previous studies have reported the positive impact of Discovery Learning on students' mathematics achievement, while other studies have demonstrated the effectiveness of PhET Interactive Simulations in facilitating conceptual understanding. However, studies examining the integration of Discovery Learning and PhET Interactive Simulations specifically for learning equivalent fractions at the junior secondary school level remain limited. In addition, only a few studies have investigated how this combination supports students in actively constructing mathematical concepts through technology-assisted exploration. This research gap indicates the need for further empirical investigation regarding the effectiveness of integrating Discovery Learning and PhET Interactive Simulations in mathematics instruction.

Based on these considerations, integrating Discovery Learning with PhET Interactive Simulations is expected to create a student-centered learning environment that promotes active exploration, conceptual understanding, and meaningful learning experiences. Through interactive investigations supported by digital simulations, students are expected to develop a better understanding of equivalent fractions and achieve higher mathematics learning outcomes than those receiving conventional classroom instruction. Therefore, this study aims to investigate the effect of Discovery Learning assisted by PhET Interactive Simulations on students' mathematics learning outcomes in equivalent fraction material at SMP Negeri 2 Padangsidimpuan.

METHODS

Research Design

This study employed a **quantitative approach** using a **quasi-experimental design** with a pretest–posttest control group design to examine the effect of Discovery Learning assisted by PhET Interactive Simulations on students' mathematics learning outcomes. The design was selected because the researcher could not randomly assign students to different

classes; therefore, existing classes were used as the experimental and control groups. Both groups completed a pretest before the instructional intervention and a posttest after the intervention to measure students' learning achievement. The differences between the pretest and posttest scores were analyzed to determine the effectiveness of the instructional treatment.

Research Setting and Participants

The study was conducted at **SMP Negeri 2 Padangsidimpuan** during the **2025/2026 academic year**. The research population consisted of all seventh-grade students. Two intact classes were selected using purposive sampling based on recommendations from the mathematics teacher and similarities in students' academic characteristics.

A total of **60 students** participated in this study. Thirty students from **Class VII-A** were assigned as the experimental group and received instruction through Discovery Learning assisted by PhET Interactive Simulations. The remaining thirty students from **Class VII-B** served as the control group and received conventional classroom instruction.

Variables of the Study

This study involved two research variables.

The **independent variable** was the implementation of the **Discovery Learning model assisted by PhET Interactive Simulations**.

The **dependent variable** was **students' mathematics learning outcomes** on the topic of equivalent fractions.

Learning Treatment

Students in the experimental group learned equivalent fractions through the Discovery Learning model integrated with PhET Interactive Simulations. The instructional activities followed six stages of Discovery Learning: **stimulation, problem identification, data collection, data processing, verification, and generalization**. During the learning process, students explored equivalent fraction concepts using interactive simulations, discussed their observations collaboratively, and constructed mathematical concepts through guided inquiry.

In contrast, students in the control group received **traditional classroom instruction**. In this study, traditional classroom instruction refers to a **teacher-centered approach** in which learning activities primarily consisted of teacher explanations, question-and-answer sessions, demonstrations using the whiteboard, and textbook-based exercises without the use of interactive digital learning media. Students mainly received information from the teacher before completing individual practice activities.

Research Instrument

The instrument used in this study was a mathematics achievement test designed to measure students' understanding of equivalent fractions. The test was developed according to the learning objectives and competency indicators contained in the Grade VII mathematics curriculum.

Table 1. Learning Outcome Indicators

No	Indicator
1	Identifying equivalent fractions
2	Determining equivalent fractions using multiplication
3	Determining equivalent fractions using division
4	Comparing equivalent fractions
5	Solving contextual problems involving equivalent fractions

Before being administered to the research participants, the instrument underwent expert validation to examine content validity. Subsequently, empirical testing was conducted to determine the validity and reliability of the test items. Only valid and reliable items were included in the final instrument used for data collection.

Research Procedure

The research was conducted through the following stages.

1. Preparing research instruments and validating the achievement test.
2. Administering the **pretest** to both the experimental and control groups before the learning intervention to determine students' initial mathematical abilities.
3. Implementing the instructional treatment according to the assigned learning model for each group.
4. Administering the **posttest** after the completion of the instructional intervention to measure students' learning outcomes.
5. Processing, analyzing, and interpreting the collected data.

Data Analysis

The collected data were analyzed using **IBM SPSS Statistics**.

Descriptive statistics, including the mean and standard deviation, were calculated to describe students' mathematics learning outcomes. Prior to hypothesis testing, prerequisite

analyses were conducted to ensure that the assumptions of parametric statistics were satisfied.

The analyses included:

1. **Normality Test** using the Kolmogorov–Smirnov test to determine whether the data were normally distributed.
2. **Homogeneity Test** using Levene's Test to examine the equality of variances between the two groups.
3. **Independent Samples t-Test** to determine whether there was a statistically significant difference in mathematics learning outcomes between the experimental and control groups.
4. **Normalized Gain (N-Gain) Analysis** to measure the improvement in students' learning outcomes after the instructional treatment.
5. **Coefficient of Determination (R^2)** analysis to estimate the contribution of Discovery Learning assisted by PhET Interactive Simulations to students' mathematics learning outcomes.

All statistical analyses were conducted at a significance level of $\alpha = 0.05$.

RESULT AND DISCUSSION

RESULT

Descriptive Statistics

Table 2. Descriptive Statistic of Learning Outcomes

Class	N	Pretest	Posttest	SD Posttest
Experimental	30	56.42	84.67	7.21
Control	30	55.18	72.35	8.18

Prior to the intervention, comparable levels of achievement were observed across the two groups, as reflected in their pretest results. Following the instructional treatment, a marked improvement was recorded in the experimental group, whose posttest performance exceeded that of the control group.

Normality Test

Table 3. Normality Test Result

Data	Sig.
Experimental Pretest	0.200
Control Pretest	0.187
Experimental Posttest	0.153
Control Posttest	0.175

All significance values exceeded 0.05, indicating that the data were normally distributed.

Homogeneity Test

Table 4. Homogenity Test Result

Data	Sig.
Posttest	0,268

The significance value of 0.268 was greater than 0.05, indicating homogeneous variances.

Hypothesis Testing

Table 5. Independent Sample t-Test Results

Variable	T-value	Sig. (2-tailed)
Learning Outcomes	6,125	0,000

The significance value of 0.000 was lower than 0.05, indicating that H_0 was rejected and H_1 was accepted. Therefore, Discovery Learning assisted by PhET simulation media significantly influenced students' mathematics learning outcomes.

N-Gain Analysis

Table 6. N-Gain Results

Class	N-Gain	Category
Experimental	0,65	Moderate
Control	0,38	Moderate

The experimental group demonstrated a higher level of learning improvement than the control group.

Coefficient of Determination

Table 7. Coefficient of Determination

Variable	R Square	Persentase
Discovery Learning Assisted by PhET	0,393	39,3 %

The results indicate that the treatment contributed 39.3% to the variance in students' mathematics learning outcomes.

DISCUSSION

The findings of this study demonstrate that students who learned through the **Discovery Learning model assisted by PhET Interactive Simulations** achieved significantly higher mathematics learning outcomes than those who received conventional classroom instruction. The Independent Samples *t*-test revealed a significance value of **0.000**, indicating that the instructional treatment had a statistically significant effect on students' understanding of equivalent fractions. Furthermore, the higher N-Gain score obtained by the experimental group indicates that integrating Discovery Learning with

interactive simulation media not only improved students' final achievement but also promoted greater learning progress throughout the instructional process.

The improvement in students' learning outcomes can be explained by the characteristics of the Discovery Learning model, which encourages students to actively construct knowledge through exploration, observation, investigation, and problem-solving activities. Unlike conventional instruction, Discovery Learning places students at the center of the learning process by allowing them to discover mathematical concepts independently under the teacher's guidance. Such learning experiences facilitate deeper conceptual understanding because students are actively involved in organizing information, identifying relationships, and drawing conclusions based on evidence obtained during classroom activities. According to Bruner (1961), meaningful learning occurs when learners actively discover concepts rather than passively receive information from teachers. Therefore, Discovery Learning provides opportunities for students to develop conceptual understanding that is more durable and transferable to new learning situations.

Another factor contributing to the effectiveness of the instructional treatment is the integration of **PhET Interactive Simulations**. Equivalent fractions are considered abstract mathematical concepts because students must understand proportional relationships among different numerical representations. Through PhET simulations, these abstract concepts become more concrete by providing dynamic visual representations that allow students to manipulate fraction models, compare equivalent values, and immediately observe the consequences of their actions. Interactive visualization enables students to connect symbolic representations with conceptual meaning, thereby reducing misconceptions and facilitating meaningful learning. Previous studies have similarly reported that PhET simulations improve conceptual understanding by providing immediate feedback, encouraging active exploration, and supporting visualization of abstract concepts (Finkelstein et al., 2005; Perkins et al., 2006; Jeno et al., 2019).

The findings of this study are consistent with previous research investigating the effectiveness of Discovery Learning in mathematics education. Fitriani and Prahmana (2021) reported that Discovery Learning significantly improves students' mathematical understanding because the instructional model promotes inquiry, critical thinking, and active participation during learning activities. Likewise, Sari and Rahmawati (2021) found that students who participated in Discovery Learning demonstrated better mathematics achievement than those taught through conventional methods. The consistency between the

present findings and previous studies strengthens the evidence that Discovery Learning is an effective instructional model for improving mathematics learning outcomes.

The positive contribution of PhET Interactive Simulations identified in this study also supports previous research concerning technology-enhanced learning. Jeno et al. (2019) emphasized that interactive digital learning environments increase students' engagement, motivation, and conceptual understanding because learners receive immediate feedback while actively exploring learning materials. Similarly, Finkelstein et al. (2005) argued that simulation-based learning provides opportunities for students to investigate scientific and mathematical concepts that are difficult to visualize through traditional instructional methods. These findings indicate that integrating technology into inquiry-based instruction can substantially improve the quality of mathematics learning.

From a theoretical perspective, the findings support **constructivist learning theory**, particularly Bruner's theory of discovery learning. Constructivism emphasizes that knowledge is actively constructed through learners' interaction with their environment rather than transmitted directly from teacher to student. Throughout the Discovery Learning process, students actively formulated hypotheses, explored mathematical relationships using PhET simulations, verified their findings, and developed conclusions independently. Such learning experiences encourage meaningful cognitive processing and strengthen conceptual understanding. Consequently, students become more capable of applying mathematical concepts to unfamiliar situations and solving problems independently.

Another important finding of this study is the increase in students' classroom participation during learning activities. Students in the experimental group were more actively involved in asking questions, discussing mathematical ideas, testing different fraction representations, and explaining their reasoning to peers. Interactive simulations created an engaging learning environment that stimulated curiosity and encouraged students to participate throughout the learning process. Increased classroom engagement has been widely recognized as one of the key factors contributing to improved academic achievement because students who actively participate tend to develop stronger conceptual understanding and greater confidence in solving mathematical problems.

Although the findings indicate that Discovery Learning assisted by PhET Interactive Simulations effectively improves mathematics learning outcomes, the contribution of the instructional treatment accounted for **39.3%** of the variance in students' achievement. This result suggests that additional factors beyond the instructional model also influence

learning outcomes. Variables such as prior mathematical ability, learning motivation, self-regulated learning, classroom interaction, and students' learning habits may also contribute to academic achievement. Therefore, future research should investigate these variables to obtain a more comprehensive understanding of the factors affecting mathematics learning.

Overall, the results of this study indicate that integrating Discovery Learning with PhET Interactive Simulations provides meaningful educational benefits. The instructional approach not only improves students' mathematics learning outcomes but also promotes active learning, conceptual understanding, critical thinking, and classroom engagement. Therefore, mathematics teachers are encouraged to integrate interactive digital technologies into Discovery Learning activities, particularly when teaching abstract mathematical concepts such as equivalent fractions. Such instructional innovation has the potential to create more meaningful, student-centered, and technology-supported mathematics learning environments.

CONCLUSION

The results of this study demonstrate that the application of Discovery Learning integrated with PhET Interactive Simulations positively influences students' mathematics learning outcomes on equivalent fractions material. Students who participated in learning activities that emphasized exploration, investigation, and interactive visualization achieved better performance than those who learned through conventional instructional methods.

The effectiveness of the instructional approach can be attributed to the complementary roles of Discovery Learning and digital simulation technology. Discovery Learning encourages learners to actively construct understanding through inquiry-based activities, while PhET simulations provide visual and interactive representations that facilitate comprehension of abstract mathematical concepts. The combination of these elements creates a learning environment that supports conceptual development and meaningful learning experiences.

The findings indicate that technology-assisted discovery learning can serve as an effective alternative strategy for mathematics instruction at the junior secondary level. In addition to improving academic achievement, the approach has the potential to increase student engagement, encourage independent learning, and strengthen problem-solving abilities. Therefore, teachers are encouraged to consider integrating interactive simulation media into classroom instruction to support more effective mathematics learning.

Future research is recommended to examine the implementation of this instructional model across different mathematical topics, educational settings, and student characteristics. Such studies may provide further insights into the broader applicability and long-term impact of technology-supported discovery learning on students' mathematical development.

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