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The influence of the team games tournament learning model assisted with the PhET application on increasing mathematic concepts of elementary school students

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ABSTRACT

This research is motivated by students' limited ability to understand mathematical concepts, the lack of diverse instructional media, the predominance of conventional teaching methods, and students' diminished motivation and interest in mathematics, particularly in solving word problems. This research aims to explore the learning process, student achievements, improvements, and the impact of implementing the Team Games Tournament (TGT) teaching approach supported with the PhET application on students' understanding of mathematical concepts in mathematics. A quasi-experimental method was employed with a nonequivalent control group design. Data collection methods included pretests (before instruction) and posttests (after instruction). Data analysis was carried out using normality, homogeneity, and hypothesis testing through t-tests and the Mann-Whitney U test. The findings reveal that the learning process when using the TGT teaching approach supported by the PhET application proceeded effectively. From the hypothesis testing results, analysis revealed a meaningful difference between the pre-test scores of the control and experimental classes, together with a substantial difference in post-test scores. This demonstrates that students' ability to comprehend mathematical concepts improved both before and after using the TGT teaching approach with PhET assistance. An effect size test showed a result that falls within the large category. Hence, the application of the TGT teaching approach, supported by the PhET application, positively influences students' ability to understand mathematical concepts.

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INTRODUCTION

The ability to understand concepts depends on students' cognitive abilities (Cahani, Effendi, & Munandar, 2021). Comprehension is a person's skill in capturing and understanding what they have learned so that they can provide more detailed and precise descriptions, illustrations, and information about what they already know and can then communicate it back to other people (Febriyanto, Haryanti, & Komalasari, 2018). Meanwhile, a concept is a person's ability to explain clearly and be able to apply it in any situation so that the person can be considered to understand the concept well (Giawa, Gee, & Harefa, 2022). Likewise, understanding concepts is a skill that captures various things that are not just recognized but can be expressed again.

However, the facts on the ground are entirely unique; they feel they are still facing challenges and still consider mathematics to be the most difficult subject. Furthermore, there is a lack of variation in instructional media, the dominance of conventional teaching methods, and low student motivation and interest in mathematics, particularly in solving word problems. In line with the research of Anggraeni, Muryaningsih, & Ernawati (2020), several things cause difficulties in learning mathematics, namely internal factors such as students' attitudes when learning mathematics, which tend to be negative; not paying attention to material information; low interest in learning mathematics; and weak motivation. Meanwhile, external factors such as teachers using monotonous learning strategies cause uninteresting and passive learning and minimal learning tools, and in the family environment, students receive less support from parents.

Understanding the concept refers to seven indicators according to Anderson & Krathwohl (as cited in Suryani, 2019), among others clarifying, illustrating, categorizing, briefing, inferring, contrasting, and describing. Permendikbud, 2014 (as cited in Mirna, Mudjiran, Aysi, & Murni, 2023) states that indicators of understanding mathematical concepts include a) restating a concept, b) classifying objects based on whether they meet specific criteria, c) recognizing the properties or operations associated with a concept, d) accurately using the concept, e) determining if something qualifies as an example of the concept, f) generating various mathematical representations of the concept, g) linking the concept to other concepts, either within or beyond mathematics, and h) establishing the essential and sufficient conditions for a concept.

This TGT or game-based learning model provides opportunities to learn calmly, increases learning engagement, responsibility, and collaboration, and creates healthy competition (Amin & Sumendap, 2022). This is in line with Sari, Ananda, & Fauziddin (2023), which states that TGT increases the ability to work together. According to (Royani & Kelana, 2022), TGT allows understanding concepts, solving problems, and solving various complex problems that they can reconsider based on the data and information they receive or investigate. TGT (Team Games Tournament) has not been implemented previously at SDN Pancasila. The school typically uses conventional teaching methods, which focus more on traditional approaches such as direct instruction and teacher-centered activities, without incorporating interactive or game-based learning strategies. The selection of the TGT (Team Games Tournament) model in this study is based on its ability to promote teamwork, healthy competition, and the development of positive attitudes among students, while also enhancing their engagement in the learning process (Anisa & Damaiyanti, 2023; Atikah, 2020; Mtk, Paraniah, Subhanudin, & Rasul, 2023). Therefore, a solution to the identified issues regarding mathematical concept understanding requires an intervention, specifically the use of the TGT teaching model assisted by the PhET application, as it can optimize the learning process. This is supported by the research of Arifin & Aprisal (2020), which demonstrates that the PhET application has significant potential in mathematics, promoting a deep understanding of the material and mathematical concepts, and thus enabling the learning process to be more effective. The PhET application is a type of game-based interactive learning media that can be accessed online via https://phet.colorado.edu. The PhET application can provide benefits to its users. The PhET simulation application, developed by the University of Colorado, is designed to model learning experiences in physics, biology, and chemistry and is intended for both hands-on and classroom-based learning (Wiravanjava, 2017). Dantic & Fluraon (2022) state that the PhET application can increase understanding significantly, make learning fun, and provide a wide choice. According to Salame & Makki (2021), PhET simulations emerged to facilitate learning and provide insight into abstract concepts. Additionally, PhET simulations provide clear instructions, are easy to follow, and offer learning opportunities that are not possible in a traditional laboratory environment.

By incorporating the TGT model with the support of the PhET application, researchers aim to actively engage students in the learning process, thereby facilitating their understanding of mathematical concepts. Research on this topic remains limited, particularly concerning the use of the TGT learning model and the PhET application across various subjects, including mathematics. What differentiates this study is the specific application of the TGT model assisted by the PhET application to enhance students' understanding of mathematical concepts in word problems, which has not been a primary focus in prior research. Furthermore, this study is conducted in the context of elementary education, utilizing an approach that integrates interactive media to create a more engaging and effective learning environment. Most previous studies have focused on improving general learning outcomes or mastery of specific concepts. For this reason, the researchers consider it crucial to explore whether the use of the TGT model, combined with the PhET application, can improve students' grasp of mathematical concepts.

METHOD

A quantitative approach was employed in this research, as it involves the use of numerical data analyzed through statistical methods. Data were gathered using research instruments and subsequently processed through quantitative analysis. This type of research is a quasi-experimental method. This study employs a nonequivalent group design, in which the treatment and conventional groups are not randomly assigned. Both groups undergo a pretest, followed by the intervention, and finally, a posttest to assess the outcomes. Nonequivalent group design steps according to Sugiyono (2017) can be explained through Table 1.

Table 1. Nonequivalent Group Design Research Design

Group	Pretest	Treatment	Posttest
Experiment	O	X	O
Control	O		O

Information:
O: Pre-test = Post-test
X: Treatment using the TGT teaching approach supported with the PhET application

The subjects of this study were all third-grade students enrolled at SDN Pancasila during the 2023/2024 academic year. The third-grade students are divided into three sections: III.1, III.2, and III.3. Additionally, this school was selected because no prior research had been conducted on understanding students' mathematical concept skills using the TGT model in conjunction with the PhET application.

In this study, two classes were selected as the research subjects: class III.3, with 31 students, served as the experimental group and was taught using the TGT model supported by the PhET application, while class III.1, with 32 students, acted as the control group and was taught using the PBL model. Both the experimental and control classes underwent the learning process over six meetings. The sample was chosen using a purposive sampling technique. The research focused on the topics of multiplication and division. Data collection methods included pretests (before instruction) and posttests (after instruction). The data analysis methods employed in this study were (1) describing the learning process with the TGT teaching approach, supported by the PhET application, using mean or average calculations; (2) performing statistical tests such as normality, homogeneity, t-tests, and Mann-Whitney U tests with the assistance of IBM SPSS Statistics 26.0 software to assess the differences in students' understanding of mathematical concepts before and after the TGT model's application; and (3) conducting an effect size test to measure the impact of the TGT model supported by the PhET application on students' mathematical concept comprehension.

RESULTS AND DISCUSSION

Overview of Students' Ability to Understand Mathematical Concepts Using the TGT Model with PhET Assistance Compared to Conventional Learning

According to research during six meetings at SDN Pancasila Lembang, classes III.1 and III.3, ability data was obtained regarding multiplication and division material in the form of pretest and posttest scores. Before starting learning, students in the experimental class and control class were given a pretest to measure their initial knowledge regarding multiplication and division material. The pretest results for the average score for the experimental group were 49.44, whereas the control group averaged 23.13. This indicates that there is a significant difference in the average scores between the two groups, as seen in Table 2.

Table 2. Pretest Average Scores: Experimental and Control Groups

Value	Mean
Pretest Experiment	49.44
Pretest Control	23.13

After conducting the pretest, at the first to fourth meetings, the researcher taught in the experimental class, and the teacher taught in the conventional class and was given two different treatments. In the experimental class, implementing the TGT teaching approach supported with the PhET application. The learning process goes well, and students are actively engaged in the learning process by applicable rules. This is in line with Fauziah & Subhananto (2016); the TGT model creates an engaging and enjoyable learning environment, as students show excitement and enthusiasm when games are integrated into the learning process. Then, the PhET application also creates a fun process. Sylviani, Permana, & Utomo (2020) PhET applications can improve student involvement and interest in the learning process. Meanwhile, conventional classes also run well.

Students consistently adhere to instructions, pay attention to explanations, take notes, and complete the worksheets (LKPD). In the experimental class, the researchers regularly implement ice-breaking activities to alleviate boredom and boost engagement throughout the learning process. Meanwhile, in the control class, the teacher did not consistently hold ice-breaking when learning had not yet started. However, the ice breaking did not last long. The students felt bored again and asked the researchers when the learning was finished, and the majority of students chatted with their group friends. However, the researchers tried to create a fun learning process. Then, the researcher showed a learning video from the YouTube page and explained the material again according to the material being discussed. Next, students work on LKPD in groups. When researchers asked students to come forward in front of the class to explain the results of their LKPD work, it was seen that some students were reluctant to come forward because they were embarrassed; this was because not all students were used to appearing in front of the class. Next, researchers entered the tournament or competition stage through the PhET application. At this stage the majority of students are enthusiastic and eager to answer the questions. However, after entering the next stage of the group award stage, namely giving prizes, there was one group who complained because their group had not continued to succeed in getting a high score. This confirms that TGT raises student motivation. In line with Nugraha & Subroto (2020), the awards given can increase students' enthusiasm for learning.

Upon completion, posttest questions are administered to evaluate the students' final abilities. The average posttest score for the experimental class was 67.78, whereas the control class averaged 30.32, as shown in Table 3. The average scores in the experimental and control groups have an average difference.

Table 3. Posttest Average Scores: Experimental and Control Groups

Value	Mean
Posttest Experiment	67.78
Posttest Control	30.32

Differences in the Average Ability of Students' Mathematical Concept Understanding between the PhET-Assisted TGT Model and Conventional Learning

a. Pretest Data Processing

Pretest data can be examined with IBM SPSS Statistics 26.0 software to determine the maximum, minimum, mean, standard deviation, and variance scores for both the experimental and control classes. Table 4 below presents the descriptive statistics from the pretest results for the experimental and control groups.

Table 4. Descriptive Statistics of Pretest Data

Value	Mean	Standard Deviation	Minimum	Maksimum	Variance
Pretest Experiment	49.44	24.993	0	88	624.641
Pretest Control	23.13	21.008	0	83	444.716

According to the data presented in Table 4, the control class obtained an average pretest score of 23.13 with a standard deviation of 21.008, while the experimental class scored an average of 49.44 with a standard deviation of 24.993. Then, it was found that the lowest score obtained by students in both the experimental and control classes was 0, indicating that the participants did not give the right answer. Meanwhile, the highest score obtained by students in the experimental class pretest was 88, and in the control class pretest was 83, where the overall winner student got the highest score. Data on average, standard deviation, minimum value, maximum value, and variance will be processed to carry out normality tests, homogeneity tests, and hypothesis tests.

1) Pretest Data Normality Test

The Kolmogorov-Smirnov and Shapiro-Wilk tests were utilized to check the normality of the pretest data for both the experimental and control classes, with a significance level of 0.05. The analysis was performed using IBM SPSS Statistics 26.0, detailed in Table 5.

Table 5. Pretest Data Normality Test Results

Kolmogorov-Smirnov Test		statistic	df	Sig.	Shapiro-Wilk statistic	df	Sig.
Values	*Pretest* Experiment	0.134	32	0.154	0.956	32	0.209
	Pretest Control	0.151	32	0.071	0.903	31	0.009

As detailed in Table 5, the Kolmogorov-Smirnov test revealed a significance value of 0.154 for the experimental class's pretest. According to the criteria for normality testing, data with a significance value above 0.05 is regarded as normally distributed, while data with a significance value below 0.05 is not. Therefore, it can be concluded that the experimental class pretest data obtained from the Kolmogorov-Smirnov test shows a normal distribution. Apart from that, as also stated in Table 5, the Kolmogorov-Smirnov significance value for the control class pretest is 0.071. This also indicates that the control class pretest data has a normal distribution. Figure 1 and Figure 2 show the distribution of experimental class pretest and control class pretest data based on the Q-Q Plot graph. As shown in the Q-Q Plot, you can see a line that represents the normal distribution of the data, where the points are scattered around this line at the observed values. It displays data deviations from normal. Then, Expected Normal refers to the expected values according to a normal distribution. The fewer points that are away from the line, the more normal the data is. Meanwhile, if more and more points move away from the line, it means the data is not normal.

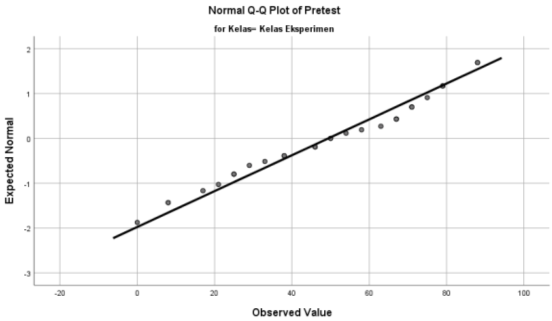

Figure 1. Normal Q-Q Plot of Experimental Class Pretest

Based on Figure 1, it can be inferred that the pretest data for the experimental class exhibits a normal distribution, as the points align closely with a straight line, suggesting adherence to a normal distribution pattern.

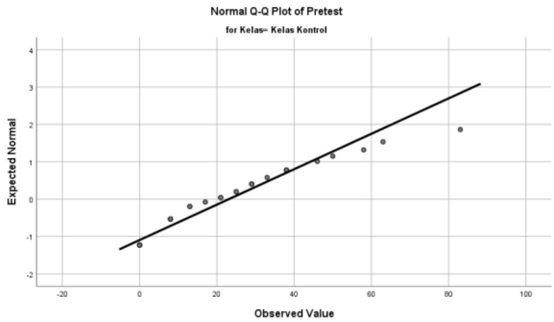

Figure 2. Normal Q-Q Plot of Control Class Pretest

In Figure 2 it is evident that the pretest data for the control class is normally distributed, as the data points are distributed around a straight line, indicating normality.

2) Pretest Data Homogeneity Test

The following step is to execute a homogeneity test or test for differences in means, as presented in Table 6.

Table 6. Pretest Data Homogeneity Test Results

Levene Statistic	df_1	df_2	Sig.
1.767	1	61	0.189

To determine data homogeneity, the significance value is examined. A significance value greater than 0.05

implies that the data is homogeneous, whereas a value less than 0.05 indicates non-homogeneity. As shown in Table 6, the significance value of 0.189 for the pretest in both classes is greater than 0.05, confirming that the data is homogeneous.

3) Pretest Data Hypothesis Testing

After conducting the normality and homogeneity tests, a hypothesis test was executed. The results confirm that the pretest data for both the experimental and control groups follow a normal distribution and exhibit homogeneity. Therefore, these results fulfill the criteria for performing hypothesis testing with the t-test. The statistical hypothesis under consideration is:

$H_0 : \mu_1 = \mu_2$
$H_1 : \mu_1 \neq \mu_2$

The following hypothesis has been proposed for this research:

H_0: The comprehension of mathematical concepts is equivalent for students taught using the TGT model with the PhET application and those taught through conventional methods.

H_1: The comprehension of mathematical concepts is not equivalent for students taught using the TGT model with the PhET application and those taught through conventional methods.

Table 7 is the hypothesis testing results for the pretest scores of both the experimental and control classes, analyzed with the t-test.

Table 7. Hypothesis Test Results Pretest Data

t	4.509
df	61
Sig. (2-tailed)	0.000

The significance value (2-tailed) in Table 7 is 0.000. Hypothesis testing follows this rule: if the significance value (2-tailed) is greater than 0.05, H_0 is accepted and H_1 is rejected; if it is less than 0.05, H_0 is rejected and H_1 is accepted. Given that the significance value is 0.000, which is under 0.05, H_0 is rejected and H_1 is accepted. This result confirms a difference in pretest scores between the experimental and control classes. Hence, H_1 is accepted, signifying a difference in mathematical concept comprehension between the TGT teaching approach supported with PhET support and the conventional learning model for third-grade elementary students or $H_1 : \mu_1 \neq \mu_2$. Furthermore, this difference can also be attributed to the initial ability differences between the two groups, rather than being solely due to the treatment provided.

b. Posttest Data Processing

To analyze the data, you can use IBM SPSS Statistics 26.0 software to calculate the largest value, smallest value, average, and standard deviation scores from the posttest for the experimental class and control class. Presented below is Table 8 which shows descriptive statistics from the posttest for the experimental class and control class.

Table 8. Descriptive Statistics of Posttest Data

Value	Mean	Standard Deviation	Minimum	Maksimum	Variance
Posttest Experiment	67.78	27.825	0	100	27.825
Posttest Control	30.32	27.838	0	92	774.959

Based on Table 8, it can be seen that the average posttest score obtained for the control class was 30.32 with a standard deviation of 27.838. Meanwhile, the average experimental class posttest score obtained was 67.78 with a standard deviation of 27.825. Then, it was found that the lowest score achieved by the student was 0, indicating that the participant did not answer correctly. Meanwhile, the largest value achieved in the treatment class posttest was 100, and the control class posttest was 92, where the maximum score obtained indicated that students had achieved the Kriteria Ketercapaian Tujuan Pembelajaran (KKTP). Average, standard deviation, minimum values, maximum values, and variance values are processed for normality tests, homogeneity tests, and hypothesis tests.

1) Posttest Data Normality Test

The distribution of posttest scores for both the experimental and control groups was assessed for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests, with a significance threshold set at 0.05. The data analysis was performed using IBM SPSS Statistics 26.0, as shown in Table 9.

Table 9. Posttest Data Normality Test Results

Test		Kolmogorov-Smirnov statistic	df	Sig.	Shapiro-Wilk statistic	df	Sig.
Values	*Posttest* Eksperimen	0.171	32	0.018	0.886	32	0.003
	Posttest Kontrol	0.200	31	0.003	0.887	31	0.003

Table 9 indicates that the Kolmogorov-Smirnov test significance value for the posttest scores of the experimental group is 0.018. According to normality test criteria, a significance value greater than 0.05 suggests that the data follows a normal distribution, while a value less than 0.05 implies that the data does not follow a normal distribution. Therefore, the posttest data for the experimental group do not conform to a normal distribution. Similarly, Table 9 shows that the Kolmogorov-Smirnov test significance value for the control group's posttest scores is 0.003, leading to the conclusion that the posttest data for the control group also does not follow a normal distribution. Figure 3 and Figure 4 below show the distribution of posttest data for the experimental class and control class based on the Q-Q Plot graph. In a Q-Q Plot, the diagonal line shows a normal distribution, where data points that are near this line indicate that the data follows a normal distribution. Points that differ greatly from the diagonal line indicate deviations from the normal distribution. Expected Normal is the expected value for a normal distribution. The fewer points that are away from the line, the more normal the data is. Meanwhile, if more and more points move away from the line, it means the data is not normal.

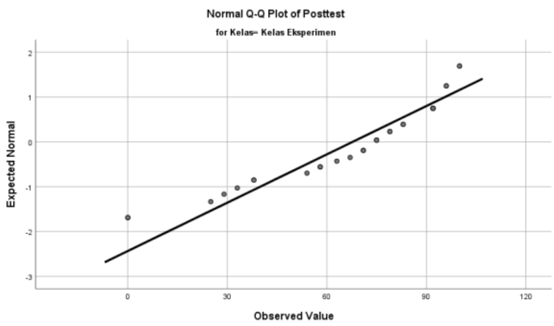

Figure 3. Normal Q-Q Plot Posttest Experimental Class

Figure 3 shows that the experimental class posttest data does not follow a normal distribution because some data points are around the linear line and some other points are far from the line. Thus, it can be inferred that the data does not exhibit a normal distribution.

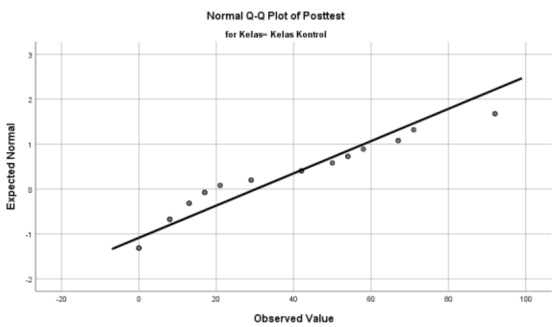

Figure 4. Normal Q-Q Plot Posttest Control Class

Based on Figure 4, it can be concluded that the control class posttest data does not follow a normal distribution because of variations in data points that surround the linear line, with several points far from the line.

2) Posttest Data Homogeneity Test

The following action is to implement a test for homogeneity or average differences, as specified in Table 10.

Table 10. Posttest Data Homogeneity Test Results

Levene Statistic	df_1	df_2	Sig.
0.211	1	61	0.647

Data homogeneity can be determined through the significance value obtained from statistical tests. Data is classified as homogeneous if the significance value is greater than 0.05, while values below 0.05 indicate inhomogeneity. Based on Table 8, the significance value for the posttest scores of both the experimental and control classes is 0.647, which is greater than 0.05, suggesting that both datasets are homogeneous.

3) Posttest Data Hypothesis Testing

The results from the normality and homogeneity tests revealed that the posttest data for both the experimental and control classes did not adhere to a normal distribution. However, the homogeneity test results show that the two data groups are homogeneous. Therefore, it does not meet the requirements to carry out hypothesis testing using the t-test. Instead, hypothesis testing on experimental class posttest and control class posttest data was carried out using the Mann-Whitney hypothesis test.

The statistical hypothesis proposed is as follows:

$H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 \neq \mu_2$

The following hypothesis guides this research:

H_0: The ability to grasp mathematical concepts does not differ between the TGT teaching approach supported by the PhET application and the conventional teaching methods for third-grade elementary students.

H_1: The ability to grasp mathematical concepts does differ between the TGT learning model supported by the PhET application and the conventional teaching methods for third-grade elementary students.

The Mann-Whitney test results for the posttest scores of the experimental and control groups are summarized in Table 11.

Table 11. Hypothesis Test Results Posttest Data

Mann-Whitney U	174.500
Wilcoxon W	670.500
Z	-4.431
Asym. Sig. (2-tailed)	0.000

Table 11 indicates that the significance value (2-tailed) is 0.000. According to the hypothesis testing criteria, if the significance value (2-tailed) exceeds 0.05, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected. Conversely, if the significance value (2-tailed) is below 0.05, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. Given that the significance value is 0.000, which is less than 0.05, H_0 is rejected and H_1 is accepted. This indicates that there are significant differences between the posttest scores of the experimental class and the control class. Therefore, it can be concluded that H_1 is accepted, demonstrating a difference in the mathematical concept understanding abilities between the TGT teaching approach supported by the PhET application and the conventional learning model for third-grade elementary students, or H_1: $\mu_1 \neq \mu_2$. The difference is also influenced by several other factors, such as the initial ability differences between the two groups, the levels of motivation and participation of students in the treatment provided, as well as the different classroom management approaches in each group, so the difference in outcomes is not solely attributable to the treatment given.

The Effect of Implementing the TGT Learning Model Assisted by the PhET Application on Students' Ability to Understand Mathematical Concepts

To find out how much influence the TGT teaching approach supported with the PhET application has on students' understanding of mathematical concepts and abilities, you can use the effect size test. The data required for calculation through the effect size test is the data from the experimental class posttest and the conventional class posttest. The hypothesis created in testing this effect size is:
Following are the calculations:

$$\delta = \frac{Y_e - Y_c}{S_c}$$

$$\delta = \frac{67.8 - 30.3}{33.4}$$

$$\delta = 1.12$$

Table 12 is the results of the effect size test.

Table 12. Effect Size Test Results

Effect Size	Category
1.12	Big Effect

Based on Table 12, the effect size of 1.12 is in the large category for students' understanding of mathematical concepts abilities. This means that 1.12 > 0.5, and then the TGT assisted by the PhET application has a big effect. This is in line with Subhan, Wathoniyah, & Karangduwur (2022), that the PhET application is quite effective in the learning process. Also in line with Marlina, Mukhlis, & Merta (2024), TGT also creates active, communicative, and fun activities.

CONCLUSIONS AND SUGGESTIONS

The findings from research conducted at SDN Pancasila Lembang on grade III elementary school students and their analysis lead to the following conclusions: The implementation of the TGT model assisted by the PhET application in mathematics learning was effective. During the six meetings, students participated very well and enthusiastically, were active, and experienced increased motivation because learning used an interactive, game-based application, namely the PhET application. Furthermore, the analysis of the average pretest scores revealed that the experimental class had an average of 49.44, compared to 23.13 for the control class. A T-test was conducted on these pretest scores, yielding a significance level of 0.000, which indicates a significant difference between the experimental and control classes. For the posttest, the experimental class averaged a score of 67.78, whereas the control class averaged 30.32. The Mann-Whitney Test was used to analyze the posttest scores, also resulting in a significance level of 0.000, demonstrating a significant difference between the posttest scores of the two classes. This indicates a disparity in mathematical understanding between students taught with the Team Games Tournament (TGT) model supported by the PhET application and those taught with the conventional model in the same grade level. Additionally, based on the results of the effect size test, there is an influence of 1.12 in the large category. Therefore, students' ability to understand concepts can be affected by the TGT teaching approach supported with the PhET application.

The research conducted at SDN Pancasila Lembang provides several recommendations for different stakeholders. For students, it is suggested that they improve their skills and interest in learning, particularly in mathematics, to encourage more active class participation. For the school, diversifying learning activities, such as incorporating the Team Games Tournament (TGT) model with the PhET application, is recommended to enrich the learning experience. Teachers are encouraged to adopt varied teaching methods, including the TGT model supported by the PhET application, to create a more engaging learning environment and enhance student motivation. Lastly, future researchers are advised to explore ways to improve students' understanding of mathematical concepts through the implementation of the TGT model in combination with the PhET application.

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