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Jump into Hopscotch: A Game-Based Approach in Enhancing Students' Proficiency in Triangle Congruence

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ABSTRACT

Triangle congruence postulates is a crucial concept in geometry. The integration of games into mathematics education is a significant development that can enhance student engagement and understanding. This research investigates the effectiveness of jump into hopscotch, a game-based approach, in enhancing students' proficiency in triangle congruence postulates. The study, employing a quasi-experimental research design, aims to determine the difference in students' proficiency between gamified and non-gamified learning instruction. A total of 61 grade 8 students from two heterogeneous sections in a public junior high school in the province of Davao de Oro, Philippines participated in the study. Results from a 30-item pre-test showed that both groups were comparable with low proficiency. After the intervention, the post-test result suggests a highly significant difference in the students' proficiency in triangle congruence postulates between the experimental and control groups, with the experimental group obtaining higher scores than the control group. The finding suggests that implementing a game-based approach, specifically jump into hopscotch, effectively enhances the students' proficiency in triangle congruence postulates. This study underscores the significance of integrating a game-based approach in learning, especially in mathematics, a subject often perceived as difficult and feared, to inform educators and researchers in the field of mathematics education.

Keywords: Hopscotch, Game-Based, geometry, triangle congruence

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INTRODUCTION

Geometry is one of the areas of mathematics that has long been thought to help students develop their critical thinking and reasoning skills. Among the many concepts involved in geometry, triangle congruence postulates are among the fundamental topics of classical geometry that students need to master in order to understand more complex geometrical concepts. Despite being fundamental, congruence of triangles is a concept that many secondary school students, especially those in the eighth grade, find challenging to understand (Shahbari and Daher, 2020).

Triangle congruence has proven to be a challenging topic for students worldwide (Wang et al., 2018). Several studies indicate that many high school students make mistakes when attempting to solve proof problems in geometry. For instance, Scristia et al. (2022) found that high school students often make errors in solving reasoning-based congruence proof problems due to a lack of symbol knowledge, misunderstandings, weak conceptual foundations, carelessness, and lack of precision. Additionally, Winer and Battista (2022), discovered that students struggle to incorporate oral reasoning into written proofs, resulting in formalization and logical gaps when solving geometry proof problems. Furthermore, Komatsu et al. (2018) noted that high school students face difficulties in proof validation in geometry because they struggle to produce diagrams that meet proof problem conditions.

In particular, grade 8 students in a public junior high school in Davao de Oro, Philippines, face significant challenges in understanding triangle congruence concepts, often confusing similar and congruent figures. This struggle is compounded by a broader perception of mathematics as a difficult subject, leading to disengagement, boredom, and lack of participation during class. Such challenges are not unique to this institution but are common in many educational settings where students grapple with abstract geometric concepts. To address these difficulties, it is essential to explore innovative teaching strategies that can increase student motivation and foster active learning.

One promising approach is gamification, which incorporates game-design elements like competition, scoring, and challenges into non-game contexts, has been shown to enhance student interest, engagement, and learning outcomes (Alsawaier, 2018). By applying gamification principles, educators can make learning more enjoyable and interactive, improving student participation and proficiency in challenging subjects like geometry. Given the difficulty students face with triangle congruence postulates, a mathematical game focused on this topic offers a relevant solution.

A particularly suitable game for this purpose is hopscotch, a traditional game, was adapted for this purpose. Instead of numbered squares, the grid featured labels or symbols representing triangle congruence postulates. Students progressed by solving problems related to these postulates, creating an interactive and engaging way to reinforce mathematical concepts.

Despite the foundational importance of triangle congruence postulates in geometry, their teaching has been notably underrepresented in existing educational literature. This gap in research and instructional practices is particularly concerning, given that triangle congruence serves as a critical building block for more advanced geometry concepts, such as similarity, transformations, and trigonometry. To bridge this gap and encourage active learning in mathematics, this study employed hopscotch, a game-based approach, as an intervention to improve students' proficiency in triangle congruence postulates. This study provides practical guidance for teachers on implementing gamification in math classes and compares the effectiveness of game-based and traditional teaching methods, highlighting the benefits of gamification in enhancing understanding and engagement.

MATERIALS AND METHODS

Research design

This quantitative study utilized a quasi-experimental pre-test-post-test design. This design involves measuring the same group of participants both before and after the intervention. Using this method, two groups are compared: one that receives the treatment (experimental group) and one that does not (control group). According to Creswell (2018), quasi-experimental techniques

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are research methodologies that resemble experimental research but exclude certain aspects of true experimentation. Marsden et al. (2012), highlight that quasi-experimental designs allow researchers to draw clearer conclusions regarding the causal relationship between two variables. The pre-test-post-test design is the most common experimental study design, with the pre-test ensuring the comparability of the two groups before the treatment and the post-test enabling researchers to ascertain the immediate effect of the treatment on the outcome variable(s).

By including a control group, researchers can determine whether any changes observed in the experimental group between the pre-test and post-test are attributable to the experimental treatment. This design is, therefore, ideal for assessing the effectiveness of the intervention, hopscotch, in improving students' proficiency in triangle congruence postulates among Grade 8 students.

Research locale and respondents

The respondents of this study were two intact, heterogeneous Grade 8 sections from San Miguel National High School, a public junior high school in barangay San Miguel, municipality Compostela, province of Davao de Oro, Philippines. The school was chosen by convenience as the researchers are assigned in the institution. Figure 1 shows the study area map.

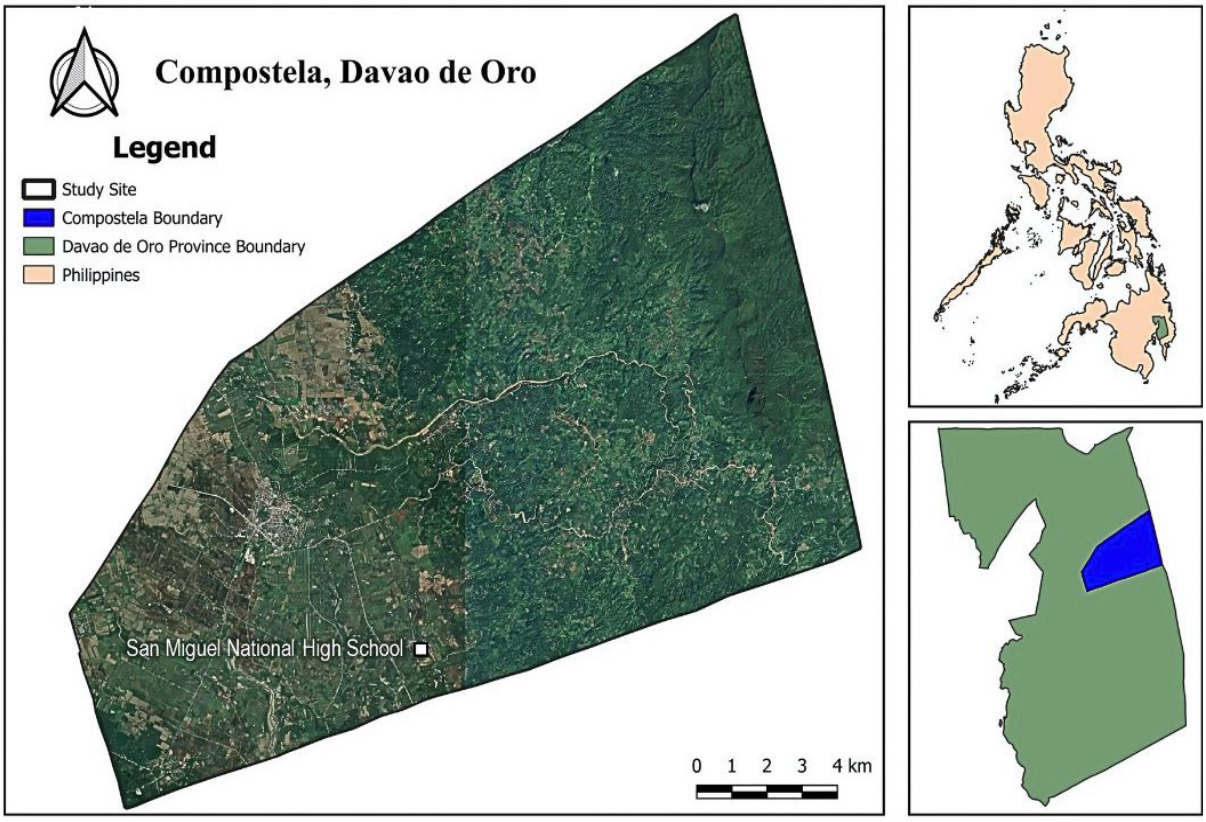

Figure 1. Study site location within Compostela, Davao de Oro, Philippines.

Initially, a pre-test was administered to all grade 8 sections to assess their proficiency levels. From these sections, two groups were randomly selected from those with mean scores showing no statistically significant difference, ensuring that the chosen sections were comparable in terms of initial performance. The experimental and control groups were then randomly assigned. The control group continued with standard teaching methods, while the experimental group was introduced to the hopscotch game approach. The experimental group consisted of 28 students, and the control group comprised 33 students, totaling 61 participants. Participation was entirely voluntary, and students could withdraw from the study at any time if they felt uncomfortable. Only completed questionnaires were included in the data analysis. Figure 2 shows of the pretest/post-test and conduct of the intervention.

Figure 2. Triangle congruence postulate discussion (A); Hopscotch implementation (B and C); Post-test (D).

Instrument

Two sets of 30-item multiple-choice questionnaires were used as research instruments. The first set was administered as a pre-test, and the second set was used for the post-test. To ensure the post-test results were not influenced by the pre-test, the two tests were designed to be different yet parallel, measuring the same competencies item by item. The questions were based on the following learning competencies: illustrate triangle congruence (M8GE-IIId-1), illustrate the SAS, ASA, and SSS congruence postulates (M8GE-IIId-e-1), and solve corresponding parts of congruent triangles (M8GE-IIIf-1). The questionnaires underwent validation by three experts in mathematics education, and revisions were made based on their comments and suggestions. The validation process yielded a mean score of 4.59, which was interpreted as very high, indicating strong validity of the instruments.

Data analysis

Descriptive statistics, including frequency distributions, means, and standard deviations, were calculated to characterize the proficiency levels and variability of scores within both groups. To interpret the mean scores obtained from the 30–item test, the parameter limits as presented below were used.

Table 1. Mean score interpretation.

Range of means	Descriptive analysis	Interpretation
24.01-30.00	Excellent	This means that the student's proficiency level in triangle congruence postulates is very high.

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18.01-24.00	Very good	This means that the student's proficiency level in triangle congruence postulates is high.
12.01-18.00	Good	This means that the student's proficiency level in triangle congruence postulates is moderate.
6.01-12.00	Fair	This means that the student's proficiency level in triangle congruence postulates is low.
0.00-6.00	Poor	This means that the student's proficiency level in triangle congruence postulates is very low.

The range of scores used to assess students' proficiency in triangle congruence postulates was structured to ensure a fair and equitable distribution across different levels of achievement. To achieve this, the maximum possible score of 30 points was divided equally into five proficiency levels. By dividing the total score equally among the categories, the researchers ensured that no one group or level of proficiency was overrepresented, and that the progression from one level to the next was both logical and fair.

T-test. The study used paired t-test and independent t-test. Paired t-tests were employed to assess within-group changes in scores following the intervention, while independent t-tests were conducted to compare pre- and post-intervention scores between the two groups. To ensure the appropriateness of parametric t-tests, normality and homogeneity of variance assumptions were examined.

Normality. To assess whether the data followed a normal distribution, both the Shapiro-Wilk test and Q-Q plots were employed. The Shapiro-Wilk test provided a statistical evaluation, while the Q-Q plots offered a visual representation of the data's distribution compared to a normal distribution. The results of the Shapiro-Wilk test are summarized in Table 2, and the Q-Q plots for each dataset are presented in Figures 3 to 6.

Table 2. Normality test summary.

Score	Shapiro-Wilk	*p*	Interpretation
Pre-test (Experimental)	0.96	.37	Normal
Pre-test (Control)	0.95	.11	Normal
Post-test (Experimental)	0.95	.23	Normal
Post-test (Control)	0.95	.13	Normal

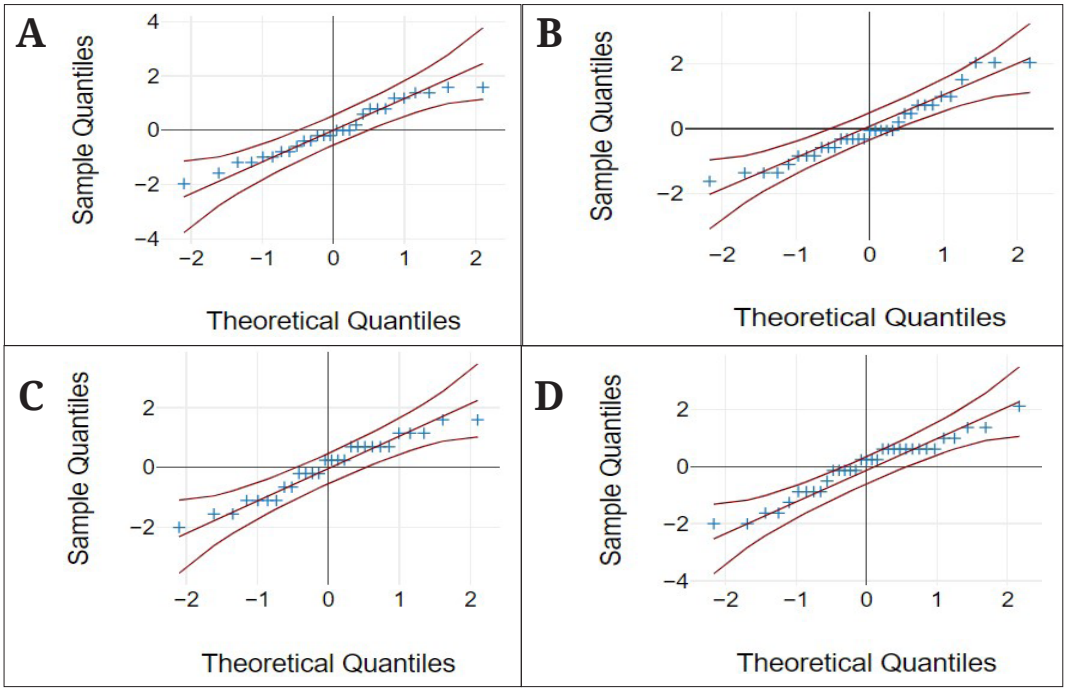

Figure 3. Pre-test (Experimental) Q-Q Plot (A); Pre-test (Control) Q-Q Plot (B); Post-test (Experimental) Q-Q Plot (C); Post-test (Control) Q-Q Plot(D).

As shown in Table 2, the Shapiro-Wilk test yielded *p*-values ranging from 0.11 to 0.374 for all datasets. Given the commonly accepted alpha level of 0.05, none of these *p*-values indicate a significant departure from normality. This finding is further supported by the visual inspection of the Q-Q plots, which demonstrate a linear pattern indicative of normal distribution.

Homogeneity of variance. A Levene's test for equality of variances was conducted to assess the homogeneity of variances across the groups. This assumption is crucial for the validity of the independent t-test. Homogeneity of variance implies that the spread of scores in each group is similar. Results indicating a non-significant Levene's test suggest that the assumption of equal variances is met. The results of the Levene's test are presented in Table 3.

Table 3. Levene test of variance equality.

Test	*F*	*p*	Interpretation
Pre-test	3.07	.085	Homogeneous
Post-test	0.66	.420	Homogeneous

As presented in Table 3, the Levene's test yielded *p*-values of 0.085 and 0.420 for the pre-test and post-test comparisons, respectively. Given the typical alpha level of 0.05, neither *p*-value is significant, suggesting that the assumption of homogeneity of variances is met for both comparisons.

Ethical considerations

The study prioritized ethical considerations, ensuring voluntary participation by informing participants of their right to withdraw at any time without consequences and emphasizing confidentiality. Vulnerability was addressed by focusing solely on grade 8 mathematics students, avoiding the involvement of vulnerable populations. To uphold integrity, researchers declared no financial or personal conflicts of interest that could bias the results. Informed assent was obtained from participants and their guardians, with detailed information about the study's objectives, procedures, and potential risks provided. Anonymity and confidentiality were rigorously maintained, with personal data protected throughout the research. Safety measures were in place to minimize potential harm, including appropriate attire, scheduled breaks to prevent fatigue, and first aid availability. The environment was designed to be supportive, ensuring that both physical and psychological well-being were safeguarded.

Moreover, the students' participation in the experiment did not influence their academic grades. The scores obtained during the pre-test and post-test, as well as their performance in the game-based intervention, were used solely for research purposes. These scores were not factored into the students' final grades, ensuring that their involvement in the study did not affect their academic standing or create undue pressure. In addition to informed consent, a debriefing session was conducted for the students of the two intact classes after the intervention. This session allowed the researchers to clarify any questions the students had about the study and to provide additional context regarding the purpose and educational benefits of the game-based learning approach.

RESULTS

Students' proficiency level before the intervention

The pre-intervention level of students' proficiency in triangle congruence postulate is presented in this section. It establishes a baseline understanding of participants' prior proficiency level in the target area. By describing students' initial competencies, it provides a foundational reference point for gauging the efficacy of the intervention. The summary of the distribution of the pre-test scores is tabulated in Table 4.

Table 4. Pre-test scores distribution.

Range of score	Description	Experimental		Control	
		f	%	f	%
24.01-30.00	Excellent	0	0	0	0
18.01-24.00	Very Good	4	14.3	0	0

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12.01-18.00	Good	7	25.0	9	27.3
6.01-12.00	Fair	13	46.4	19	57.6
0.00-6.00	Poor	4	14.3	5	15.1
		28	100	33	100
	Total				
	Mean	12.00		10.21	
	SD	5.07		3.81	
	Description	Fair		Fair	

Table 4 presents the pre-test scores distribution of the experimental and control groups in triangle congruence postulates. The data reveals that a significant portion of students in both groups fell into the "Fair" category, which is interpreted as a low proficiency level. Additionally, similar percentages were observed in the "Good" category, interpreted as moderate proficiency level, as well as in the "Poor" category (very low proficiency level). Notably, while the experimental group achieved a slightly higher mean score, the scores were more dispersed compared to the control group, which had a slightly lower mean but less variability in scores.

A visual representation of the comparison of pre-intervention proficiency levels between the experimental and control groups is provided in Figure 7. This figure offers a complementary perspective on the data presented in Table 4, allowing for a more intuitive understanding of the distribution of proficiency levels across both groups.

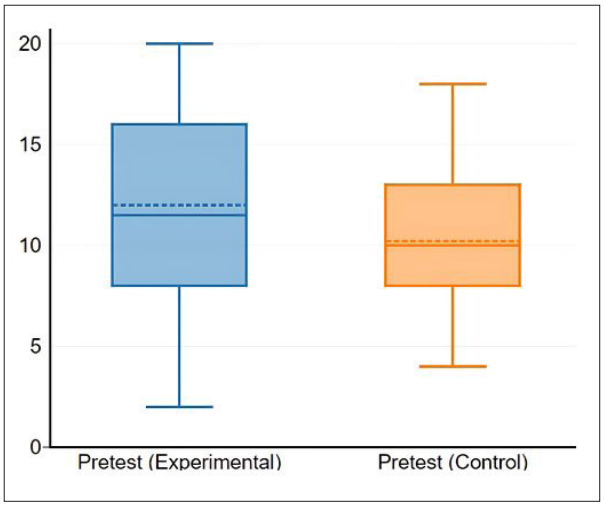

Figure 4. Pre-test scores box plot.

The box plot in Figure 7 visually summarizes the pre-intervention proficiency levels in triangle congruence postulates for the experimental and control groups. It can be noted that while both groups exhibit a comparable mean score, the interquartile range is notably wider for the experimental group, indicative of a greater dispersion of scores within this group. This suggests a higher degree of heterogeneity in the experimental group's proficiency, with students demonstrating a broader range of understanding compared to their counterparts in the control group. Additionally, no outliers are visible in either group, suggesting that the data points are relatively clustered within the expected range.

Students' proficiency level after the intervention

This section presents the students' proficiency levels in triangle congruence postulates following the implementation of the intervention. The experimental group underwent a gamified learning experience utilizing the hopscotch approach, while the control group received traditional instruction. The post-intervention performance of both groups is summarized in Table 5.

Table 5. Post-test scores distribution.

Range of score	Description	Experimental		Control	
		f	%	f	%
24.01-30.00	Excellent	5	17.8	1	3.0
18.01-24.00	Very good	22	78.6	22	66.7
12.01-18.00	Good	1	3.6	10	30.3
6.01-12.00	Fair	0	0	0	0
0.00-6.00	Poor	0	0	0	0
	Total	28	100	33	100
	Mean	22.46		19.36	
	SD	2.22		2.68	
	Description	Very good		Very good	

Table 5 presents the distribution of post-test scores of students in the experimental and control groups in triangle congruence postulates. The data reveals significant improvements in both groups compared to their pre-intervention levels. The "Very good" range saw the majority of students from both groups. This indicates that most students in both groups attained a high level of proficiency following the intervention, though the experimental group had a slightly higher concentration in this range.

In the "Excellent" range, more students in the experimental group achieved this highest level of proficiency, compared in the control group. This suggests that the intervention was particularly effective for a subset of students in favor of the experimental group. Moreover, only a small portion of students in the experimental group scored in the "Good" range, while a third of students in the control group fell into this category. Notably, no students in either group scored in the "Fair" or "Poor" ranges, demonstrating that the intervention, hopscotch approach, and traditional method successfully moved all students out of the lowest proficiency levels.

Table 5 presents the mean scores for the experimental and control group, both of which fall under the "Very good" category. This indicates a high level of proficiency in triangle congruence for both groups. Additionally, the table highlights that the scores within the experimental group were more consistent, with a lower standard deviation, compared to the control group's slightly higher standard deviation. This suggests that the game-based approach in the experimental group not only resulted in higher performance but also more uniform learning outcomes. The results presented in Table 5 are visually depicted in Figure 8.

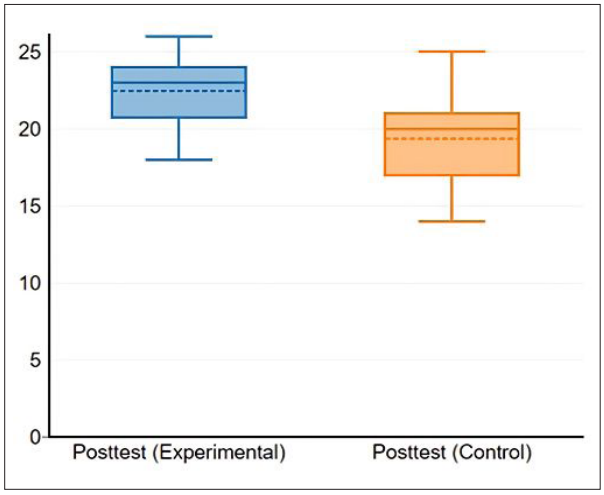

Figure 5. Post-test scores box plot.

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To determine whether there exists a statistically significant difference between the pre-test and post-test performance of both groups, a paired *t*-test was used. The result of the test of difference is shown in table 6.

Table 6. Difference between the pre-test and post-test scores.

Group	*t*	df	*p*	Interpretation
Experimental	-9.98	27	<.001	Significant
Control	-12.3	32	<.001	Significant

Table 6 presents the *t*-test results comparing the pre-test and post-test scores for both the experimental and control groups. For the experimental group, $t\ (27) = -9.98,\ p < .001$, suggests that the improvement in post-test scores was highly significant. This indicates that the game-based approach implemented in the experimental group had a substantial positive impact on students' proficiency in triangle congruence postulates. Similarly, for the control group, $t\ (32) = -12.3,\ p < .001$, also showed a significant improvement in post-test scores. The increase in mean scores for both groups emphasize the effectiveness of both instructional approaches—game-based using the hopscotch approach for the experimental group and traditional for the control group—in enhancing students' proficiency. The significant improvement in proficiency levels indicates that both methods contributed positively to the students' understanding of triangle congruence postulates. However, further analysis would be required to determine if one approach was more effective than the other in achieving greater gains in learning outcomes.

Difference between the post-test scores of the experimental and control group

To determine if there was a statistically significant difference between the post-test scores of the experimental and control groups, an independent *t*-test was conducted. This statistical test is crucial for comparing the means of two groups to assess whether any observed differences are likely due to the intervention or simply a result of random variation. The results of the independent *t*-test were summarized in Table 6.

Table 7. Test of difference summary.

Mean	*t*	df	*p*	Cohen's d	Interpretation
3.10	4.87	59	<.001	1.25	Significant

Table 7 summarizes the results of the statistical analysis comparing the post-test scores between the experimental and control groups. The mean difference of 3.10 indicates that the experimental group scored, on average, 3.10 points higher than the control group. The *t*-value, $t\ (59) = 4.87$, $p < .001$, suggests that this difference between the two groups is substantial. The *p*-value, which is less than .001, indicates that the difference is highly statistically significant, meaning that the likelihood of this result occurring by chance is extremely low. Furthermore, the Cohen's d value of 1.25 represents a large effect size. This suggests that the impact of the game-based strategy used in the experimental group was not only statistically significant but also practically meaningful, demonstrating a strong and positive influence on students' proficiency.

DISCUSSION

During pretest, both groups were classified within the "Fair" category, indicating a low proficiency level before any intervention. This suggests that most students had only a fair understanding of triangle congruence postulates. These baseline results highlight the necessity for targeted instructional strategies to improve students' proficiency in this area. This finding aligns with the study by Masinading and Gaylo (2022), which also reported low pre-test scores among learners, indicating poor academic achievement and not meeting the minimum standards. Evardo and Itaas (2024), reported similar reports which are likely because students lack prior exposure to the topic. More importantly, these results underscore the importance of

effective learning approaches to enhance learners' academic performance. Without incorporating effective teaching methods, students' academic achievement is likely to suffer. This emphasizes the critical role of innovative and targeted instructional strategies in the teaching and learning process to ensure better academic outcomes for students.

Meanwhile, the post-test results show that incorporating hopscotch into teaching and learning across various fields and contexts has demonstrated significant improvements in student outcomes. For instance, hopscotch has been shown to enhance students' vocabulary (Alvisar and Malik, 2016), foster a positive attitude towards programming (Wang, 2021), and develop higher-order thinking skills in early childhood education (Fajzrina et al., 2024). Additionally, hopscotch has proven to be an effective instructional tool. Ismaiyah and Fadhilawati (2022), found that the developed hopscotch board served as a valid and effective alternative medium for teaching reading of descriptive texts in junior high schools. Similarly, Sarafiah and Khatimah (2023), demonstrated that incorporating the traditional hopscotch game into ethnomathematics learning media was effective in teaching geometry. These studies highlight the versatility and effectiveness of hopscotch as a pedagogical tool across diverse educational contexts.

Several studies highlight the advantages of game-based learning approaches in education. For instance, research by Che Mansor and Rosly (2024), found that Digital Game-Based Learning (DGBL) significantly enhances students' achievement in mathematics. Iffah et al. (2024), demonstrated that flashcard media, when incorporated into a game-based learning environment, is an effective tool for improving both collaboration skills and student achievement. Similarly, Kartika (2023), found that the Kahoot game-based problem-based learning model effectively boosts student motivation and academic performance in calculus.

These findings align with earlier research by Lin and Cheng (2022), which showed that both game-based and traditional teaching methods effectively improve student performance. Francisco (2023), also confirmed that traditional teaching approaches can positively impact student achievement. Additionally, Amzalag et al. (2024), emphasized that while traditional teaching methods are effective, integrating digital games into practice can further enhance student engagement and academic outcomes. Collectively, these studies u nderscore the importance of adopting diversified teaching strategies that incorporate both traditional and game-based approaches to cater to students' varied needs and learning styles, thereby addressing multiple intelligences and improving overall achievement.

Incorporating a variety of instructional approaches can create a more engaging and inclusive classroom environment. By providing students with multiple opportunities to participate in activities that align with their interests and strengths, teachers can ensure that each student has an equal chance to succeed. Furthermore, a diversified approach allows students to explore and master their potential through exposure to different instructional methods, fostering greater engagement, motivation, and overall academic growth. This highlights the need for educators to integrate a range of strategies to better support individualized learning and maximize student performance.

Comparing the post-test results show that the experimental group significantly outperformed the control group in post-test performance, demonstrating that the game-based approach, jump into hopscotch, led to greater improvements in understanding triangle congruence postulates than traditional methods. This aligns with previous studies, such as Karakoç et al. (2020), which reported a large effect size for traditional game-based learning on student achievement, and Wang et al. (2022), who found that digital game-based STEM education had a moderate positive impact on learning outcomes. Beyond cognitive gains, game-based strategies have been shown to boost student motivation, engagement, enjoyment, and focus (Vankúš, 2021). Together, these studies highlight the potential of both traditional and digital game-based learning approaches in boosting student achievement, highlighting the value of incorporating such strategies into the classroom to engage students and enhance their understanding of complex concepts. These results suggest that mathematics teachers should consider incorporating game-based strategies into their instruction to maximize student achievement.

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The results of the study support the Constructivist Learning Theory, which posits that learners actively construct their own understanding and knowledge of the world through experiences and interactions. According to this theory, students learn best when they are actively engaged in hands-on activities that promote problem-solving and critical thinking. The use of a game-based learning approach such as jump into hopscotch aligns with this framework, as it encourages students to interact with mathematical concepts in an engaging and dynamic way, allowing them to apply their knowledge of triangle congruence postulates through meaningful experiences. The significant improvement in post-test scores among the experimental group reinforces the idea that when students are provided with engaging, student-centered learning activities, they are more likely to achieve higher levels of understanding and proficiency.

CONCLUSION

Based on the results of the study, it can be concluded that the game-based learning approach significantly enhances students' proficiency in triangle congruence postulates, outperforming the traditional teaching method. Practically, the result highlights the effectiveness of integrating game-based strategies in mathematics education, offering a more engaging and interactive way of teaching and learning. Theoretically, the study supports the Constructivist Learning Theory, demonstrating that active, student-centered learning environments promote better knowledge construction and critical thinking skills.

However, the study has limitations that future research could address. First, it focused on a specific mathematical concept—triangle congruence postulates—and results may not generalize to other areas of mathematics or different subject domains. Additionally, the study was conducted within a limited time (six sessions), which may restrict the broader application of the findings. Future research should explore the long-term effects of game-based learning across diverse mathematical topics and in larger, more varied student populations. Further studies could also examine how game-based learning interacts with different student demographics, such as age, learning styles, and academic backgrounds. Moreover, research on integrating digital games and technology-based platforms into the classroom could provide further insights into optimizing student engagement and academic achievement in mathematics.

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AUTHOR CONTRIBUTIONS

Conceptualization, J.M.P., N.J.T., and O.J.E; methodology, J.M.P., N.J.T., and O.J.E; software, O.J.E; validation, J.M.P., N.J.T., and O.J.E; formal analysis, J.M.P., N.J.T., and O.J.E; investigation, J.M.P. and N.J.T.; resources, J.M.P. and N.J.T.; data curation, J.M.P. and N.J.T.; writing – original draft preparation, J.M.P. and N.J.T.; writing – review and editing, O.J.E; visualization, O.J.E; supervision, O.J.E.

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