Enhancing Students' Performance in Geometry through the Use of Tangram

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ABSTRACT

This study investigates the effectiveness of tangram puzzles in enhancing Grade 8 students' geometry performance. Conducted during the 2023–2024 school year, the research was situated in a single section of Grade 8 students, chosen through purposive sampling. The study employed a classroom-based action research design, utilizing lesson plans, pre-tests, and post-tests as instruments. Data analysis involved descriptive statistics such as frequency, percentage, mean, and standard deviation, along with statistical tools like the t-test and HyperRESEARCH for qualitative analysis. Findings reveal that students struggled with geometry before the intervention, indicating a need for improvement. However, after implementing tangram, there was a significant improvement in students' performance, shifting their scores from below satisfactory to outstanding. Tangram proved particularly beneficial for hands-on learners, enhancing their understanding and enjoyment of geometry. The study recommends regularly integrating tangram into geometry lessons and suggests further research to explore its long-term effects and integration into other subjects. Overall, the study underscores the effectiveness of tangram in enhancing students' geometry performance, making abstract concepts more accessible and enjoyable.

Keywords: geometry, students' performance, tangram

CONTEXT AND RATIONALE

The need to enhance students' performance in Geometry was prevalent. This matter is underscored by the Program for International Student Assessment (PISA) rankings in 2022 for Mathematics, where the Philippines positioned sixth out of the ten countries, garnering an average score of 355. Geometry, a fundamental branch of Mathematics, is crucial in shaping analytical thinking, problem-solving skills, and overall mathematical competence. Students need to enhance the learning experience to understand the abstract concepts of Geometry.

Mathematical connection is connecting mathematical concepts and their settings outside mathematics. As measured by the three indications of connection ability, mathematical connection ability is often low. Students did not understand the ideas they had been studying; it is easy to forget concepts, principles, and procedures; they are not used to using concepts, principles, and procedures; they believe mathematics has nothing to do with other sciences; they are not accustomed to applying mathematical concepts in everyday life; and they do not understand the story (Kleden et al., 2021).

Moreover, self-regulated learning practices and students' motivation and academic achievement are linked in mathematics. It demonstrated statistically significant positive connections between self-regulated learning and intrinsic motivation, extrinsic motivation, task value, control of learning beliefs, self-efficacy, and academic accomplishment (El-Adl & Alkharusi, 2020). Students' emotional intelligence, self-esteem, and self-efficacy impact their academic performance in mathematics. Emotional intelligence, self-esteem, and self-efficacy were significant predictors of students' academic achievement in mathematics. Thus, emotional intelligence, self-esteem, and self-efficacy significantly predict students' mathematical ability (Ugwuanyi et al., 2020).

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However, teacher collaboration affected students' academic progress in mathematics. There was a substantial difference in the influence of teachers' groups (collaboration versus isolation) on students' mathematical proficiency. Furthermore, student age has no significant effect on academic achievement in mathematics (Saka, 2021).

In addition, there is growing evidence that spatial instruction improves mathematics achievement in early childhood education. However, fewer studies have been conducted in secondary school settings, typically more discipline-driven. Differences in spatial and mathematics performance after the intervention, assessed using Hierarchical Linear Modeling, revealed that the intervention group (32 classes) improved significantly more on spatial reasoning and mathematics achievement than the business-as-usual control group (eight classes). Compared to the control group, the intervention group improved in geometry, measurement, and number and algebra content (Lowrie et al., 2021).

Using tangram puzzles in elementary education is well-established for enhancing geometric understanding. Hence, only a few studies have focused on using tangram to improve the performance of Grade 8 students. To fill this gap, it is necessary to examine the student's level of performance before and after using tangram.

INTERVENTION

Creating a mental image of our spatial world is essential in developing abstract geometric thinking. Building a mental image can be considered a step in visualizing (Kmetová & Nagyová Lehocká, 2021). Over time, instructional materials such as manipulatives have enhanced students' understanding of mathematical concepts. These materials are a vital resource in student learning, both as a recreational tool that encourages motivation and as a dynamic tool for grasping concepts in which students participate in learning activities (Ponte et al., 2023).

Geometry is a branch of mathematics that requires creative thinking. Teachers need a geometry instrument that is enjoyable, accessible, and useful for assessing junior high students' creative thinking abilities. The developed tangram-based geometry test was valid, feasible, and practical (Cahyanita et al., 2021).

The proposed tangram intervention aims to enhance students' performance in geometry during the School Year 2023 – 2024. Tangram is an educational game consisting of seven pieces of flat shape forms created by an ancient Chinese, Yang-cho—chü-shih, during the reign of Chia—Ch'ing (1796 – 1820). Tangram can be employed in Grade 8 geometry classes, where students can utilize the shapes for problem-solving while simultaneously creating various figures. This utilization can contribute to enhancing their overall performance.

The challenge in the tangram game is to arrange the pieces into an example form, such as people, houses, birds, cats, or other shapes. Thus, constructivist learning requires media to help teachers and students understand geometric concepts (Anggraeni et al., 2023).

Based on the Program for International Student Assessment (PISA) results in 2022 for Mathematics, the Philippines was positioned sixth out of the ten countries. The researcher proposed using tangram intervention to enhance students' geometry performance. The researcher planned to develop a tangram puzzle model that the class could collectively construct. This hands-on activity was integrated into the geometry discussion. This intervention aimed to enhance the geometry learning experience for Grade 8 students, foster a deeper understanding of geometric concepts, and improve overall performance.

Action Research Questions

This action research aimed to address the performance of students in geometry. Specifically, this study sought to answer the following questions:

1. What is the level of performance of the students in geometry before the use of tangram?
2. What is the level of performance of the students in geometry after the use of tangram?
3. Is there a significant improvement in the students' level of performance after the use of tangram?

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4. What other developments among the learners after the use of tangram?

Research Design

The study used a classroom-based action research design to enhance students' geometry performance through tangram. Action design research, or ADR, has gained widespread recognition as a significant research methodology in information systems (Cronholm & Göbel, 2022).

Site

The study was conducted at the junior high school level, specifically among the Grade 8 students at a public secondary school in Ozamiz City. The school was a complete secondary school open to learners from Grade 7 to Grade 12.

Participants

The study's respondents were the 37 Grade 8 students from one section the researcher taught. They were selected through purposive sampling. The respondents were selected based on the following criteria: students who were enrolled as Grade 8 students for the school year 2023–2024, students who were observed to have low performance, and students who were willing to participate in the study. The researcher ensured that these criteria were met before conducting the survey. However, the researcher did not include other sections of the same grade level in the study.

Data Gathering Methods

Pre-Implementation Phase

The researcher looked at current challenges students face in learning about geometry. They explored existing studies to gain a broader understanding of the research topic. Afterward, the researcher will begin outlining the research proposal and seek permission from the division superintendent of Ozamiz City to conduct the research. During the field study, lesson plans were developed, and pre-tests and post-tests were made to ensure the intervention was well-structured. The assessment instruments were appropriately made to assess the students' improvement. The data collection and intervention were done in person, using face-to-face communication.

Implementation Phase

During the implementation stage, data was gathered, starting with a pre-test given to the participants. The researcher applied the planned intervention to the participants for a set period. The intervention was conducted for a month, during which continuous monitoring of the participant's performance and attitude occurred. A post-test assessment followed this. Data retrieval, tallying, analysis, and interpretation were also carried out. The data analysis phase helped the researcher determine the effectiveness of the intervention and whether it was significantly effective.

Post-Implementation Phase

In the post-implementation stage, the researcher drew conclusions, provided recommendations, and carefully reviewed, edited, and finalized the research study. Additionally, the research results were shared correctly with a specific group.

Ethical Issues

According to the study's ethical standards, the subjects' informed consent was obtained before the survey. As part of ethical practice, the researchers gave participants a full briefing on the Data Privacy Act 2012 to demonstrate their commitment to protecting personal information and ensuring accountability when dealing with sensitive data. Throughout the procedure, participants were fully informed about the study's objectives, potential benefits, and the importance of their participation. The researchers also emphasized the confidentiality of the obtained data and assured participants that their anonymity would be preserved

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throughout the study.

Data Analysis Plan

The researcher computed descriptive statistics to determine the mean and standard deviations of the level of performance before and after the intervention. The following statistical tools were utilized:

Mean and Standard Deviation were used to summarize students' performance levels before and after using tangram.

T-Test was used to explore the significant difference in students' performance before and after using tangram.

Thematic Analysis was used to create themes from the interview data, facilitating a qualitative analysis of the participants' experiences and attitudes using HyperRESEARCH Software.

RESULTS AND DISCUSSION

By incorporating tangram in teaching geometry to Grade 8 students, it successfully enhanced their understanding, engagement, and performance in the subject. Using tangrams provided a hands-on, visual learning experience that made abstract geometric concepts more accessible and enjoyable. Through careful analysis of the student's pre-test and post-test results, the researcher demonstrated the significant positive impact of tangram on students' geometry scores, from did not meet expectations to outstanding. This feedback provides valuable insights for educators, enabling them to refine their teaching methods and improve student outcomes effectively.

Table 1 shows the students' geometry performance before implementing the tangram intervention. Before the implementation of the tangram intervention, most of the students were struggling with geometry. These results indicate a significant need for intervention, as most students struggled with their geometry performance. The low mean score and the high percentage of students not meeting expectations underscore the importance of implementing new teaching strategies, such as tangram, to improve students' understanding and performance in geometry.

The pre-intervention data demonstrate many students' difficulties when learning geometry, indicating a significant need for educational interventions. This shows the potential of tangrams as an essential teaching tool for geometry, mainly because of their capacity to materialize abstract geometric ideas.

Decades of research have shown that many students find it challenging to solve geometry-proof problems. There were noticeable variations in the frequency with which students in the two groups displayed specific skills and behaviors. The areas where students' understanding of the proof assumptions, the warrants in their arguments, and their logical reasoning needed to be improved were the areas with the most differences (Cirillo & Hummer, 2021).

To assist students in developing their critical thinking skills and mathematical concepts, learning geometry strongly emphasizes experimenting with various representations, such as written math formulas, virtual manipulatives, and spoken explanations. The study's conclusions showed that students struggled more to understand geometry concepts, such as making diagrams for a given geometric problem and using many theorems to solve a given geometric problem. Additionally, students' interests in the geometry component and their family history impact how well they learn geometry. Furthermore, the teaching experiment's outcomes show that student-based learning strategies outperform traditional geometry teaching techniques (Juman et al., 2022).

Tangram allows students to perceive and manipulate shapes directly, which has the potential to improve their comprehension and increase their level of involvement in the classroom. These experiential learning opportunities are essential for deeper understanding and can significantly improve students' comprehension of complex geometric relationships and concepts.

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Table 1. Performance of the Students in Geometry Before the Use of Tangram

Performance	Frequency	Percentage	M	SD
Fairly Satisfactory (FS)	3	8.11	11.00	0.00
Did Not Meet Expectation (DME)	34	91.89	6.971	2.067
Overall Performance	37	100	7.297	2.271

Note: Scale: 17-20 (Outstanding); 15-16 (Very Satisfactory); 13-14 (Satisfactory); 11-12 (Fairly Satisfactory); 1-10 (Did Not Meet Expectation)

Student performance has significantly increased once tangram was introduced into geometry classes. While the tangram technique benefited most students, only a small percentage did not achieve expectations after the intervention.

The development of manipulatives made it easier for students to understand concepts in mathematics, particularly geometry (Anggraini et al., 2023). Tangram games help users develop their numeracy skills for the following reasons: (a) they help develop the ability to deal with abstract concepts and apply them to concrete situations; (b) they help shape a positive mindset toward success and goal-achieving; (c) they help students see the big picture rather than focusing on the minute details; and (d) they help improve word problem-solving abilities (Pascual, 2020).

The results demonstrated that a range of offered activities might investigate students' prior knowledge and foster informal knowledge, serving as a link to help them comprehend the comparison of values and turning values. Students' understanding of comparative concepts and the context of tangram problems is stimulated by drawing sections of objects that need to remain intact. This allows students to model and express challenges. Additionally, as students' strategies progressed, they became more formal in mathematics. The area model was used to represent the tangram's comparative situation and a model for more formal reasoning techniques like division of the tangram image and multiplication of comparisons between values and turns value in problem-solving (Wasiran, 2020).

This change in performance also suggests that manipulative and visual aids like tangrams in educational contexts can promote deeper learning. Students' physical manipulation of tangrams has improved their spatial grasp of geometric ideas, which can be difficult to explain using traditional teaching techniques.

Table 2. Performance of the Students in Geometry After the Use of Tangram

Performance	Frequency	Percentage	M	SD
Outstanding (O)	32	86.49	18.813	1.091
Very Satisfactory (VS)	3	8.11	15.333	0.577
Satisfactory (S)	1	2.70	13.00	-
Did Not Meet Expectation (DME)	1	2.70	10.00	-
Overall Performance	37	100	18.135	2.162

Note: Scale: 17-20 (Outstanding); 15-16 (Very Satisfactory); 13-14 (Satisfactory); 11-12 (Fairly Satisfactory); 1-10 (Did Not Meet Expectation)

Table 3 compares students' performance in geometry before and after they used tangram in their lessons. The

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change in scores from those who did not meet expectations to those who were outstanding shows how effectively tangram helped students understand and excel in geometry.

This significant increase in scores demonstrates that tangrams make learning geometry more accessible and enjoyable by allowing students to manipulate shapes physically. This mainly benefits students who learn better through hands-on activities and visual aids, as it clarifies abstract geometry concepts.

Students who are more involved in their education attain higher levels of academic accomplishment when teachers provide environments in the classroom where students can demonstrate strong involvement in the study of geometry. This effort aims to raise student engagement levels in geometry classes by utilizing enthusiastic teachers and culturally appropriate teaching to enhance academic accomplishment (Murphy, 2020).

This study shows that spatial learning may be implemented successfully in a secondary school setting and mpacts students' mathematics performance when taught by classroom teachers (Lowrie et al., 2021).

The data indicates that incorporating tangrams positively and statistically significantly impacted the participants' performance. The pre-test and post-test results demonstrate that integrating tangrams as a learning tool improved outcomes in the measured variable.

Table 3. Difference in the Performance of the Students in Geometry Before and After the Use of Tangram

Variables	M	SD	t-value	p-value	Decision
Before Using Tangram	7.297	2.271	26.02	0.000	Reject Ho
After Using Tangram	18.135	2.162			

Note: Probability Value Scale: **p<0.01 (Highly Significant); *p<0.05 (Significant); *p>0.05 (Significant); p>0.05 (Not Significant)

Ho: There is no significant difference in the performance of the students in geometry before and after the use of tangram.

Improvement Highlights after the Use of Tangram

After using tangram, the teacher observed significant improvements in students' engagement, interest, and motivation in geometry class. Tangram increased enjoyment and engagement, making learning more interactive and fun. Students demonstrated improved confidence in solving geometry problems, as they could physically manipulate the shapes to understand and prove triangle congruence. Additionally, tangram helped students better understand shapes and their properties, enhancing their knowledge of geometric concepts.

Increased Enjoyment and Engagement

Using tangram in geometry class made learning much more fun and engaging for students. They felt like they were playing a game, making it easier to understand complex ideas. One student compared it to creating pictures, turning lessons into a creative activity. Another student thought it was like solving a puzzle, where they could actively move pieces around to see how shapes fit together. Overall, tangrams helped make geometry more exciting and accessible by turning lessons into hands-on activities. The responses of the participants stress this:

“Tangram made learning easier like playing a game.” (P1)

“Learning geometry was fun, like creating pictures.” (P2)

“Learning was hands-on and like solving a puzzle.” (P4)

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When teachers used standard textbooks and teaching tools to conduct lessons when teaching geometry shapes mathematical concepts in the past, students were unable to comprehend the principles fully. This study investigates how students' acceptance of technology, learning motives, and performance are affected when utilizing a virtual reality immersive learning system for mathematics geometry. The outcome of the trial showed that students' learning motivation and performance may be enhanced by employing the virtual reality immersive learning mathematics geometry system (Su et al., 2022).

A thorough literature review is done, including definitions, key advantages, methods of manipulatives, and the instructor's role regarding these three concepts. Students can attain intellectual comprehension of abstract mathematical concepts when combined with manipulatives, student engagement, and problem-solving strategies (Monte, 2021).

Using tangram puzzles makes learning geometry more enjoyable and engaging for students. They feel like they are playing a game, which helps them understand complex ideas better. Students compare it to creating pictures or solving puzzles, making lessons more interactive and hands-on. Traditional teaching methods with standard textbooks only partially help students grasp geometric concepts. Tools like tangrams and virtual reality can boost students' motivation, understanding, and performance in geometry.

Improved Confidence in Solving Geometry Problems

After using tangram, students felt more confident in solving geometry problems. They were able to understand and prove geometric concepts, like triangle congruence. By actively engaging with tangram and applying them to geometry problems, students gained the confidence to tackle more challenging tasks. This increased confidence improved their performance and encouraged them to participate more actively in class discussions and activities. The claim was supported by participants 2 and 3:

"I felt more confident understanding proofs." (P2)

"Ma'am, I am more confident seeing how to prove congruence." (P3)

Reflective math students typically have self-confidence in solving arithmetic problems quickly. Assumptive, virtual, and connected thinking are the three categories of reflective thought identified by the study's findings. The three classes' approaches to handling confusion are different. Meanwhile, there are commonalities among the three categories. Despite a few indicators that needed to be fulfilled, the students generally used every aspect of reflective thinking. These included organizing ideas before tackling difficulties, applying effective methods, and connecting ideas. Students need more participation or a low level of activity in reflective thinking, which is the factor. Furthermore, they need to comprehend the goals of the problem and believe that providing accurate answers to the questions is the most crucial thing (Kholid et al., 2020). Incorporating learning theories and discovery learning may enhance students' confidence, mathematical reasoning, and communication in geometry. Compared to traditional knowledge, the Discovery Learning Module significantly impacts student engagement (Siregar et al., 2020). Teaching tangrams in school fosters a more profound comprehension of measuring and spatial awareness (Powell & Fanshawe, 2022).

Using tangram puzzles boosts students' confidence in solving geometry problems. They become better at understanding and proving concepts like triangle congruence. This confidence leads to better performance and more active participation in class discussions and activities. Reflective thinking helps students organize ideas and apply effective methods when solving problems. Discovery learning and tools like tangrams make geometry more engaging, improving students' reasoning and communication skills.

Better Understanding of Shapes and Their Properties

Students could better comprehend shapes and their characteristics by using tangrams. By constructing and disassembling shapes, they could observe and investigate their characteristics. Tangram gave students a practical way to learn, enabling them to interact with geometric ideas and expand their comprehension directly. These exercises helped students understand the properties of shapes and how they connect, which improved their understanding of geometry and made it easier to understand. Participants proved this claim:

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"It helped me see properties by creating and taking apart shapes." (P2)

"Tangram helped me understand properties by building shapes." (P5)

"The use of tangram helped me understand properties by manipulating shapes." (P10)

Students who are more visual-spatial exhibit higher levels of creative thinking. This suggests that visual-spatial students have superior creative thinking abilities when learning mathematics, particularly in geometry (Aini et al., 2020). The post-test rankings showed a significant difference between the two groups' usual achievement of mathematical concepts. This study offers more proof of the advantages of manipulative use. The achievement scores of students who utilized manipulatives were higher (Iqbal et al., 2020).

Students' geometric competencies correlate with their spatial and planar geometric skills. To develop these skills, students can use various 2D and 3D geometric puzzles, manipulatives in real-world and virtual environments, a variety of perspectives (projections) of objects in the plane, and a wide range of other problems necessitating the application of interplay between spatial and planar viewing and imaging (Kmetová & Nagyová Lehocká, 2021).

Tangram puzzles help students understand shapes and their properties better. Students can see and explore geometric characteristics directly by building and taking apart shapes. This hands-on approach makes learning geometry more practical and more accessible to grasp. Students with solid visual-spatial skills benefit even more, showing improved creative thinking and higher achievement in geometry. Overall, tangrams and other manipulatives enhance students' geometric skills by providing interactive and engaging learning experiences.

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The study addressed the prevalent need to improve students' performance in geometry, highlighted by low rankings in international assessments and challenges in understanding abstract geometry concepts. The primary purpose of this study is to investigate the effectiveness of using tangram puzzles in enhancing the performance of Grade 8 students in geometry. Existing research has identified factors such as mathematical connection ability, self-efficacy, self-regulated learning practices, emotional intelligence, and teacher collaboration as influential in mathematics achievement. However, more research is needed on using tangram puzzles to enhance the performance of Grade 8 students in geometry.

The study was conducted during the school year 2023–2024 at the junior high school level, specifically with Grade 8 students. The research site was a single section of Grade 8 students, chosen through purposive sampling based on low performance and willingness to participate in the study. Other sections of the same grade level were not included in the study.

Findings

The following were the study's key findings:

1. Students struggled with geometry before incorporating tangram, as indicated by low mean scores and a high percentage of failing to meet expectations. This underscores the need for intervention to improve geometry understanding.

2. After implementing tangram, students' performance in geometry significantly improved. The change in scores from below satisfactory to outstanding demonstrates the effectiveness of tangrams in enhancing students' understanding and performance.

3. The data shows a statistically significant improvement in students' performance after using tangram. Tangram helped make geometry more accessible and enjoyable, particularly for students who benefit from hands-on activities and visual aids.

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4. Tangram improved students' performance and increased their enjoyment and engagement in geometry class. Through hands-on activities with tangrams, students felt more confident solving geometry problems and better understood shapes and their properties.

Conclusions

The study's results led to the formulation of the following conclusions:

1. Before using tangram, students were struggling with geometry. They had low average scores, and many needed to meet the expected standards. This highlighted a clear need for some form of intervention to help them improve.

2. After tangram was introduced into the classroom, students' performance in geometry improved significantly. Their scores went from below satisfactory to outstanding, showing that tangrams were very effective in helping students understand and do better in geometry.

3. The data showed that the improvement in students' performance after using tangrams was statistically significant. This means the change was not just by chance; tangrams helped students learn geometry better, especially those who learn well with hands-on activities and visual aids.

4. Using tangram boosted students' geometry skills and made the class more enjoyable. Through the engaging, hands-on experience of working with tangram, students felt more confident about solving geometry problems and developed a better understanding of shapes and their properties.

Recommendations

1. Teachers may incorporate tangram into their geometry lessons. This hands-on tool has proven effective in improving students' understanding and performance in geometry.

2. Schools may offer professional development for teachers on effectively using tangrams and other visual aids in their teaching methods to enhance students' learning experiences.

3. Develop various tangram-based activities and exercises to cater to different learning styles. This will help engage all students and make learning geometry fun and interactive.

4. Regularly monitor students' progress and assess the effectiveness of tangrams in the classroom. Adjust teaching strategies based on these assessments to continuously improve student outcomes.

5. Schools may promote the use of other hands-on learning tools and activities across different subjects to foster a more engaging and interactive learning environment.

6. Future researchers may explore the impact of other visual and hands-on aids on different areas of mathematics and other subjects to identify additional practical teaching tools. This will help build a broader understanding of how these aids can support student learning.

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