Remittances Review
September 2024
Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

Received: 16 July 2024, Accepted: 05 August 2024

Effectiveness of Tangram-Based Learning in Enhancing Geometric Knowledge at the Elementary Level

Shumaila Malik1, Prof. Dr. Muhammad Naeemullah2, Prof. Dr. Rabia Tabassum2, Asst. Prof. Sajid Rehman3

1. PhD Education Scholar, Northern University, Nowshera.
2. Department of Education, Northern University, Nowshera.
3. Department of Education, Northern University, Nowshera.

ABSTRACT

The study was aiming at exploring the effectiveness of Tangram-based learning in enhancing geometric knowledge at elementary level. The objectives of the study were:(i): To explore themean achievement scores of female students in geometry before the experiment, (ii): To explore the effectiveness of tangram on **knowledge aspect** of geometrical achievement of female studentsTo achieve the above objectives, the null hypotheses were tested: (i): There is no significant difference in mean achievement scores of female students in geometry before the experiment, (ii): There is no significant difference in knowledge aspect of geometry between the two female groups after the experiment.Total 40 students of 8thgrade were taken as sample ofthe study. The sample students were divided into experimental and control group by paired random sampling technique. Each group comprises of 20 students of 8th class. True experimental pretest-posttest equivalent group research design was used. Both the groups were provided the same learning material (course content). Control group was taught with traditional method (lecture demonstration method), while experimental group was taught by using the manipulative i.e., tangram for the period of six academic weeks. For data collection tests were developed. To measure the performance of the students, statistical techniques such as descriptive statistics and t-test were applied. The results of the study indicated that there was significant effect of tangram on the performance of the students and enhanced their knowledge. It was recommended that the teaching geometry concepts through tangram should be included in the curriculum. The study is significant for curriculum developers, teachers, students and other researchers.

Key words: Effectiveness, Tangram, Geometry, Elementary Level.

Introduction

The use of Tangram puzzles in geometry education has gained attention for enhancing students' spatial reasoning, problem-solving, and understanding of geometric concepts (Clements &Sarama, 2016; Zhao et al., 2018). Widely used in classrooms worldwide, Tangrams help students explore shapes, transformations, and figure relationships. Research shows they promote deductive reasoning and construction skills through interactive learning (Zhang & Wang, 2019). Unlike traditional methods focused on memorization, Tangrams offer a hands-on approach that deepens understanding. This active learning style boosts engagement and retention (Liu & Wu, 2020).

In Khyber Pakhtunkhwa (KPK), Pakistan, integrating Tangrams into elementary geometry education offers a practical solution to students' learning challenges. Traditional methods often emphasize theory, limiting hands-on understanding. Tangrams promote visual-spatial reasoning, shape recognition, and deductive skills (Hussain, Ahmed, & Zafar, 2020). This study explores their effectiveness in improving students' geometric knowledge. It will assess how Tangram-based instruction compares to traditional approaches. The goal is to determine if it leads to better performance in geometry (Clements &Sarama, 2016; Zhao, Wang, & Li, 2018).

The Role of Tangram Puzzles in Enhancing Geometry Education

Traditional methods of teaching geometry have prompted interest in innovative tools like Tangram puzzles. Tangrams, made of seven geometric pieces, offer a hands-on, interactive way to explore shapes and spatial relationships. They help students connect abstract concepts with physical manipulation (Xin, 2018). This approach makes geometry more accessible and engaging. It also boosts students' motivation and learning outcomes (Furner & Worrell, 2017).

Singh (2004) highlights tangrams as effective manipulative tools that promote geometric thinking and reasoning in young learners. A tangram is an ancient Chinese puzzle made of seven geometric pieces—two large triangles, one medium triangle, two small triangles, a square, and a parallelogram (Tian, 2012). These basic shapes can form various polygons and creative figures like animals or objects. Tangrams help children develop geometry concepts by sorting, comparing, and solving puzzles (Lin et al., 2011). Through hands-on manipulation, students better understand spatial relationships, positions, and structural features (NJMCF, 1995). This tactile learning strengthens their intuitive grasp of geometry. Studies show tangrams boost observation, creativity, logical thinking, and vocabulary in geometry (Olkun et al., 2005; Yang & Chen, 2010; Bohning&Althouse, 1997).

Tangram and the knowledge Aspect of Geometry

Geometry knowledge includes understanding shapes, area, perimeter, angles, and symmetry (Sarama& Clements, 2016). Mastering these concepts is essential for advancing in math. It supports problem-solving and prepares students for more complex topics. This foundation is key to progressing from arithmetic to advanced reasoning (Clements &Sarama, 2015). Tangram puzzles provide an engaging, hands-on way to explore geometric concepts. By rearranging tans, students observe changes in area, perimeter, and symmetry (Li & Ma, 2019). This interaction reinforces understanding through active learning. It also fosters inquiry and discovery, deepening geometric insight.

Research shows that manipulatives like Tangrams improve students' understanding and retention of geometry. Cheng (2020) found that students using Tangrams outperformed those taught through traditional methods. The visual, interactive nature helps internalize concepts more effectively. Studies show that Tangram-based instruction benefits students of varying academic levels. Low achievers gain from the hands-on approach, making abstract concepts more accessible (Luo &Zuo, 2020). High achievers can deepen their understanding through complex challenges. Tangrams support diverse learning needs in geometry. This research will explore their impact across academic levels.

Statement of the Problem

Teaching geometry at the elementary level presents notable challenges, particularly in developing students' geometric understanding through traditional methods, which often fail to engage learners or make abstract concepts accessible. These limitations contribute to low achievement and gaps in geometric reasoning. As a result, there is growing interest in using educational manipulatives like Tangram puzzles to enhance comprehension. Tangrams offer a hands-on, interactive approach that allows students to physically explore geometric shapes and relationships, potentially improving engagement and understanding. Despite promising research, there remains a gap in evaluating how specific tools like Tangrams affect geometry learning. This study aims to examine the effectiveness of Tangram puzzles in enhancing the knowledge aspect of the cognitive domain. It investigates the extent to which Tangram-based instruction improves students' understanding and how it compares to traditional teaching methods in promoting deeper learning of geometric concepts.

This research was conducted to fill this gap, offering a nuanced analysis of the effectiveness of Tangrams in fostering a well-rounded geometric education at the elementary level. That is why the researcher conducted her research titled "*exploring the effectiveness of Tangram-based learning in enhancing geometric knowledge at elementary level*".

Rationale of the Study

Integrating effective teaching tools in elementary education is crucial for building a strong foundation in mathematics, especially geometry, which fosters logical thinking, spatial reasoning, and problem-solving. In Pakistan, traditional lecture-based methods often fail to engage students or address diverse learning needs, leading to difficulties in grasping geometric concepts. This highlights the need for innovative approaches like Tangram puzzles, which offer a hands-on, visual method for exploring geometry. This study examines the effectiveness of Tangram puzzles in enhancing knowledge acquisition at the elementary level. Understanding their impact is vital, as knowledge in geometry involves recognizing shapes, properties, and spatial relationships. Research suggests Tangrams can significantly improve these learning outcomes by making abstract concepts more interactive and accessible (Nesher, 2015; Lee & Kim, 2016).

So the researcher conducted the research titled "*Exploring the Effectiveness of Tangram-Based Learning in Enhancing Geometric Understanding at the Elementary Level*".

Purpose of the Study

This study aimed to assess the impact of Tangram-based activities on students' acquisition of fundamental geometric knowledge and problem-solving skills. It also sought to evaluate their effectiveness in improving performance and to provide practical recommendations for integrating Tangrams into the geometry curriculum.

Objectives of the Study

Objectives of the study were:

1. To explore the mean achievement scores of female students in geometry before the experiment.
2. To explore the effectiveness of tangram on knowledge aspect of geometrical achievement of female students.

Hypothesis of the Study

To achieve the objectives of the study the following null hypotheses were tested.

$H_0 1$: There is no significant difference in mean achievement scores of female students in geometry before the experiment.

$H_0 2$: There is no significant difference in knowledge aspect of geometry between the two female groups after the experiment.

Significance of the Study

The study provided the appropriate use of tangram for the teaching concept of geometrical figure at elementary level. The study will bring changes in teaching methodology. The study will provide information to the concerned authorities to take appropriate steps to teach geometry. It will be helpful for the curriculum developers of teachers' training programs to include such teaching aids in their curriculum for the teaching of mathematics. So, that students can study geometry with interest and will be motivated towards learning and understanding of geometrical concepts. Finally, this study will addresses the issue of how students feel about geometry and provide educators with evidence-based insights into the potential benefits and limitations of incorporating Tangram puzzles into geometry education, ultimately contributing to the development of more effective teaching strategies at the elementary level.

Literature Review:

Knowledge aspect in Geometry

Hansen and Larson (2010) explored the impact of dynamic geometry software on students' comprehension of geometric concepts. The study focused on the use of this software and its effect on students' acquisition of geometric knowledge. A quasi-experimental design was implemented with a sample of 150 high school students, using pre- and post-tests to assess their knowledge. The results indicated that students who used the dynamic geometry software demonstrated a significant improvement in their understanding of geometric concepts compared to those who received traditional instruction. The study concluded that integrating technology into geometry teaching can enhance conceptual understanding.

Lee and Kim (2012) examined how various types of visual representations (e.g., diagrams, 3D models) influence students' acquisition of geometric knowledge. The study focused on factors such as the type of visual representation, student engagement, and knowledge retention. Employing a randomized control trial, the research involved 200 participants from several elementary schools. The results indicated that students who were exposed to multiple forms of visual representations gained a deeper understanding of geometric concepts. Additionally, the study highlighted that utilizing a variety of visual tools can accommodate different learning styles, thus improving overall geometric knowledge.

Sweller and Chandler (2014) examined the effect of cognitive load on students' ability to learn and apply geometric knowledge. The study aimed to determine the ideal level of cognitive load that promotes learning without causing students to feel overwhelmed. Variables included cognitive load, instructional design, and student performance. Using an experimental design, the study sampled 180 middle school students. The results showed that a moderate cognitive load facilitated better understanding and retention of geometric knowledge, while excessive load hindered learning. The study highlighted the importance of carefully designing instructional materials to manage cognitive load effectively.

Johnson and Ahn (2016)focused on the impact of collaborative learning on the development of geometric knowledge. The study aimed to determine whether students working in groups could enhance their understanding of geometry compared to those working individually. The key variables were group work, individual work, and knowledge outcomes. The study used a comparative analysis with 100 high school students divided into group and individual work settings. The findings indicated that students engaged in collaborative learning showed greater improvement in geometric knowledge, particularly in problem-solving and reasoning skills. The study concluded that collaborative learning fosters deeper understanding and application of geometric concepts.

Tzuriel and Egozi (2017) explored the connection between students' spatial ability and their understanding of geometric concepts. The study aimed to examine how spatial ability impacts the learning of geometry. Key variables included spatial ability, geometric knowledge, and gender differences. The sample consisted of 250 elementary school students, with spatial ability tests and geometry assessments used to gather data. The findings showed a strong correlation between spatial ability and geometric knowledge, with boys typically outperforming girls in spatial tasks. The study highlighted the importance of implementing targeted interventions to assist students with lower spatial abilities in geometry education.

Turner and Baker (2018) examined how the use of manipulatives, such as geometric shapes and models, influences students' understanding of geometric knowledge. The study's aim was to explore whether hands-on learning could enhance geometric knowledge acquisition. The variables included the use of manipulatives, student engagement, and knowledge outcomes. A quasi-experimental design was employed with a sample of 180 elementary students. The results revealed that students who utilized manipulatives had a stronger understanding of geometric concepts compared to those who depended solely on textbook instruction. The study concluded that manipulatives are effective tools for improving geometric knowledge, particularly in younger students.

Kaur and Singh (2019) conducted a longitudinal study to track the development of geometric knowledge over time among students. The study aimed to understand the progression of geometric understanding from elementary to high school. The key variables were time, instructional methods, and knowledge retention. The study followed 300 students over six years, using annual assessments to measure their geometric knowledge. The findings indicated that consistent exposure to geometric concepts, combined with varied instructional methods, resulted in steady improvement in geometric knowledge. The study highlighted the importance of sustained and diverse instructional approaches in geometry education.

Nesher and Peled (2021**)** explored the differences in students' geometric knowledge development when taught through conceptual versus procedural instruction. The study aimed to determine which instructional approach better supports geometric knowledge. The variables were instructional method, student engagement, and knowledge retention. The study involved 160 middle school students and employed a pre- and post-test design. The results indicated that conceptual instruction fostered a deeper understanding and longer retention of geometric knowledge, while procedural instruction was more effective for short-term skill acquisition. The study recommended a balanced approach that integrates both instructional methods.

Remittances Review
September 2024
Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

In a recent study, Gutiérrez and Rico (2023) investigated gender differences in the acquisition of geometric knowledge. The study aimed to determine if there were notable differences in how male and female students learn geometry and to identify the factors contributing to these differences. The main variables included gender, instructional methods, and geometric knowledge outcomes. A mixed-methods approach was used with a sample of 220 middle school students. The results indicated that, although some differences in spatial reasoning were observed, they did not result in significant disparities in overall geometric knowledge. The study suggested that addressing stereotypes and providing equitable learning opportunities are key to minimizing gender disparities in geometry education.

Relationship between Tangram and Knowledge Aspect in Geometry

In their 2011 study, "Early Childhood Mathematics Education Research: Learning Trajectories for Young Children," Sarama and Clements built upon previous research by focusing on the role of Tangram puzzles in fostering geometric knowledge and problem-solving skills in young learners. The study, which involved a sample of kindergarten students, employed a mixed-methods approach that included pre- and post-tests as well as classroom observations. The researchers found that Tangram activities enhanced students' understanding of geometric concepts and improved their ability to solve geometric problems (Sarama& Clements, 2011).

A notable investigation by Zhang and Wang (2015), entitled "Tangram-Based Instruction and Its Impact on Geometric Knowledge and Skills," sought to examine the influence of Tangram-based pedagogy on the geometric competencies and knowledge of middle school students. The study encompassed a sample of 100 students and utilized a quasi-experimental design, incorporating pre- and post-assessments to gauge shifts in geometric comprehension. The findings revealed that Tangram-based instruction resulted in substantial advancements in students' geometric understanding and problem-solving abilities, underscoring the efficacy of Tangram activities in enhancing geometry education (Zhang & Wang, 2015).

In 2023, Turner and Green conducted a seminal inquiry titled "Assessing the Role of Tangram Puzzles in Developing Early Mathematical Concepts," with the intent to critically appraise the contribution of Tangram puzzles to the cultivation of nascent mathematical concepts, particularly within the realm of geometry. The investigation engaged a cohort of 100 preschool-aged children, utilizing a mixed-methods paradigm that integrated both quantitative assessments and qualitative observational analyses. The researchers concluded that Tangram puzzles are efficacious in augmenting foundational mathematical comprehension and honing problem-solving acumen, thereby underscoring the pivotal role of manipulatives in early childhood pedagogy (Turner & Green, 2023).

Method and Procedure

Population

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

All the elementary students in the subject of mathematics studying in government sector schools of KPK.

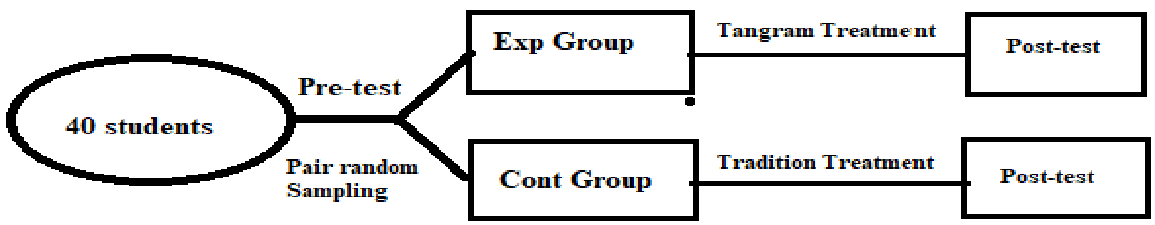
Sample

In this study, 40 Grade-8 girls from a Government Girls High School in NowsheraCantt were selected from a pool of 60 using simple random sampling. They were then equally divided into experimental and control groups through pair random sampling based on pretest scores. This method ensured balanced groups for comparison (Farooq, 2001).

Research Design

The study used a pre-test and post-test equivalent group design to assess the treatment's effectiveness (Farooq &Tabassum, 2017). This design compares outcomes before and after the intervention using two equivalent groups.

Symbolic Representation of Research Design:



Research Instruments

The researcher developed a pre-test based on Grade-8 geometry content, administered to all students before dividing them into experimental and control groups. A post-test, consisting of 25 multiple-choice questions, was given after six weeks of treatment to measure students' knowledge. Each question was worth one mark, focusing on basic geometric concepts.

Validity of the Pre-Test and Post-Test

Validity ensures a test measures what it is intended to measure (Farooq, 2001). To ensure this, the post-test was reviewed and refined based on feedback from six mathematics experts. Their input confirmed the test's validity and guided necessary modifications (Shroch& Coscarelli, 2007).

Reliability

The reliability of the pre-test and post-test was assessed using the split-half technique, dividing the questions into Test-A (even) and Test-B (odd). The tests were administered to 36 students, and the reliability coefficient, calculated using Pearson's formula, was 0.85, indicating high reliability.

Treatment

For completing the treatment, two teachers of the same experience (ten years) and same qualification (M.Sc Mathematics) were selected, one for the experimental

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

group and another for control group. Three chapters from Mathematics grade 8^{th} textbook were selected for the teaching. These three chapters have following topics:

Chapter # 1 Practical Geometry

Topics: Square, its properties and construction, Parallelogram, its properties and construction, Kite, its properties and construction, Right Angled Triangle, its properties and construction

Chapter # 2 Area

Topics: Right Angled Triangle using Pythagoras Theorem, Area of Triangular region using Hero's Formula

Chapter # 3 DemonstrativeGeometry

Theorem # 1: In any correspondence of two triangles, if two sides and included angle of one triangle are congruent to the corresponding sides and included angle of the other, the two triangles are congruent.

Theorem # 2: If two sides of a triangle are congruent, then angle opposite to these sides are congruent.

Theorem # 3: An exterior angle of a triangle is greater in measure than either of its opposite interior angles.

Theorem # 4: The sum of measures of the three angles of a triangle is 180^0.

Above mentioned topics were taught to both groups over a period of six weeks. Lesson plans were created for the sessions, and both the experimental and control groups were observed by the researcher. The control group received instruction using the traditional lecture-demonstration method, while the same course content was covered for both groups. At the conclusion of the six weeks, a post-test was administered to the sample students.

Lesson Plans

The researcher created two sets of lesson plans: one for teaching with Tangrams, a manipulative tool, and another for traditional teaching methods. Each set covered six weeks, with forty-minute classes and specific objectives for each lesson. The lesson plans for the experimental group focused on using Tangrams, where students actively engaged with the material and followed the teacher's guidance to explore geometric concepts. The teacher facilitated the learning process, encouraging students to replicate their own experiences and solve problems. In contrast, the control group followed traditional lesson plans, using textbooks, whiteboards, and notebooks in a conventional classroom setting.

Procedure

Forty 8th grade mathematics students were selected using pair random sampling and administered a pre-test to assign them into control and experimental groups based on their scores. The study took place over six periods per week, each lasting 40 minutes. Two sets of 34 lesson plans were prepared, one for each group, covering the same content with identical objectives. The control group received traditional lectures, while the experimental group used Tangram puzzles to learn the material. Both groups were taught at the same time but in different locations.

In the first week, on first day, a pre-test on selected 8th grade math topics was administered. After this, the experimental group received a detailed introduction to Tangrams, including their history and use in learning geometry, with each student given a small Tangram set and the teacher a larger display set. Topics like "Square" and "Parallelogram" were taught through Tangrams, with students using the shapes to explore properties and constructions. The control group, meanwhile, learned the same topics through traditional lecture methods. Students in both groups were instructed to record the geometric shapes and solved problems in their notebooks.

In the second week, the experimental group learned about "Kite" and "Right Angled Triangle" using Tangram shapes to explore their properties and construction. Students matched shapes from their Tangram sets with those displayed on the blackboard by the teacher, and then pasted them into their notebooks with solved problems. The control group learned the same topics through traditional lecture methods. The experimental group was actively involved in explaining properties, making the lesson more engaging. Both groups followed the same curriculum but with different teaching methods.

In the third week, the experimental group learned the Pythagoras Theorem and revised previous topics using Tangram sets, focusing on right-angled triangles. The teacher demonstrated the properties and applications of the triangle on the blackboard, and students actively engaged in understanding the topic. The control group learned the same material through traditional lectures. Both groups covered the same content, but with different teaching methods.

In the fourth week, the experimental group learned about Hero's Formula for measuring the area of a triangle, starting with the differences between it and the Pythagoras theorem. Students used Tangram sets to explore triangle shapes, with the teacher displaying them on the blackboard. Properties and construction of triangles were taught interactively, and students pasted shapes in their notebooks with solved problems. The control group learned the same topic through traditional lectures. Both groups covered the same content but with different instructional methods.

In the fifth week, the experimental group learned about theorems related to triangles, starting with the concept of theorems and related terms like proof and postulates. The teacher introduced two theorems: congruence of triangles based on sides and angles, and congruent angles when two sides of a triangle are equal. Students used Tangram sets to explore shapes, while the teacher displayed them on the blackboard. The control group learned the same material through traditional lectures. Both groups studied the same content using different teaching methods.

In the sixth week, the experimental group learned Theorem #3 (exterior angle of a triangle) and Theorem #4 (sum of triangle angles is 180°), along with related

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

terms like proof and postulates. Students used Tangram sets to explore shapes, and the teacher displayed them on the blackboard to teach the properties and construction of triangles. Theorems were then taught with Tangram tools. The control group learned the same material through traditional lectures. Both groups covered the same topics but with different teaching methods.

On last day of the research, after completing the lecture, post-test was conducted for sample students**.**

Data Collection

Two research assistants administered the pre-test and post-test, each with three multiple-choice options, within a fixed time of 30 minutes. After marking the tests, the assistants recorded the scores for both groups, categorizing them by performance level. The pre-test was used to randomly divide students into the experimental and control groups. The experimental group received instruction using Tangrams, while the control group was taught through lectures. The post-test, conducted after six weeks, assessed the effectiveness of Tangrams in teaching geometry.

Training of Research Assistants (Mathematics Teachers) for Study

Two teachers with 10 years of experience and M.Sc. Mathematics qualifications were assigned to the experimental and control groups. Prior to the experiment, a one-week training was conducted to familiarize them with the lesson plans, study duration, and teaching methods. This training ensured consistency in the study's execution.

Analysis of Data

The data were analyzed using mean scores to assess overall performance and t-tests to determine significant differences between the experimental and control groups' pre-test and post-test scores.

ANALYSIS AND INTERPRETATION OF DATA

The collected data were analyzed and interpreted by using mean scores and t-test in the light of the objectives of the study.

$H_0 1$: There is no significant difference in mean achievement scores of female students in geometry before the experiment.

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

Table 4.1: Performance of Control and Experimental group before treatment.

	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
PRE EXP GROUP	**Pre-Exp**	20	15.0000	3.87977	.86754
	Pre-Cont	20	14.9500	3.67746	.82230

The table 4.1 shows the performance of experimental and control group before the experiment commence. It shows that the groups were almost equal in pretest before experiment.

Table 4.2: Comparison of mean scores of experimental and control groups in pre-test.

Pre-test (Exp and Cont group)	**Levene's Test for Equality**	**t-test for Equality of Means**

Remittances Review
September 2024
Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

	of Variances					
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Diff**
Equal variances assumed	.059	.809	.042	38	.967	.05
Equal variances not assumed			.042	37.892	.967	.05

Levene's test showed a p-value of 0.809, confirming homogeneity of variances across the groups. The independent-sample t-test for pre-test scores showed tcal = 0.042 and p = 0.967, indicating no significant difference between the groups. This suggests the two groups were similar before the experiment began.

Post-test analysis

To check the performances of two groups after experiment, both the groups were tested by post-test.

H_02: There is no significant difference in knowledge aspect of geometry between the two female groups after the experiment.

Table 4.3: Performance about knowledge aspect of control and experimental group in posttest.

	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Posttest	**Exp**	20	21.1000	2.59351	.57993
	Cont	20	18.9500	2.74293	.61334

Table 4.3 shows that the experimental group had a higher mean score of 21.10 compared to the control group's 18.95, suggesting better performance in the post-test. The difference in mean scores (2.15) implies that the Tangram intervention positively impacted the experimental group's knowledge. The standard deviations were 2.59 for the experimental group and 2.74 for the control group, indicating a similar range of scores. The standard error of the mean was slightly smaller for the experimental group (.57993), suggesting a more precise estimate of the true mean. Overall, the experimental group's higher mean score indicates the effectiveness of the intervention.

Remittances Review
September 2024
Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

Table 4.4: Comparison of means of knowledge aspect of two groups on post-test

Post-test (Exp and Cont group)	**Levene's Test for Equality of Variances**		**t-test for Equality of Means**			
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Diff**
Equal variances assumed	.248	.621	2.547	38	.015	2.15

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

Equal variances not assumed			2.547	37.892	.015	2.15

Table 4.4 compares the post-test means of the experimental and control groups. Levene's Test for Equality of Variances showed an F-value of 0.248 and a p-value of 0.621, indicating that the variances between the groups are equal ($p > 0.05$). This confirms that the t-test results can be interpreted under the assumption of equal variances.

The t-test revealed a t-value of 2.547 with 38 degrees of freedom and a p-value of 0.015, indicating a significant difference between the experimental and control groups. The mean difference of 2.15 suggests the experimental group scored higher. Since the p-value is less than 0.05, we reject the null hypothesis and conclude a statistically significant difference in the post-test means.

In summary, the findings demonstrate that the Experimental group performed significantly better than the Control group in the post-test, with a notable mean difference of 2.15. This suggests that the intervention applied to the Experimental group had a positive effect on their knowledge aspect performance.

Hence it was concluded that the using tangram in instruction of geometry significantly affected the performance of the experimental group in comparison with control group who were taught in tradition way.

Discussion

The $\mathbf{H_{02;}}$ To explore the effectiveness of tangram on **knowledge aspect** of geometrical achievement of female students, was rejected. It was concluded that the tangram instruction significantly improved the level of experimental group in comparison

Volume: 9, No: S 4, pp.1416-1435
ISSN:2059-6588(Print)|ISSN2059-6596(Online)

of control group on knowledge, understanding and construction skill. These results are aligned with the research results of the study of Saleem and Aziz (2017). Ding and Jones (2006) also revealed that the instruction method is the main causal factor in the development of student geometrical thinking.

Conclusions

The main conclusions of the study are:

(i) Before the experiment the two groups were almost the same, (ii) Tangram in instruction of geometry significantly affected the performance of the experimental group in comparison with control group who were taught in tradition way,(iii)The tangram treatment did significant effect on the level of knowledge of experimental group in comparison to control group.

Recommendations

On the basis of this experimental study results, analysis and conclusions the following recommendations are made:

1. Tangram activities should be integrated into the curriculum to enhance student engagement and knowledge of geometry. It helps make abstract concepts more accessible and improves student achievement.
2. Teachers need well-structured lesson plans that incorporate tangram activities to ensure effective learning. Clear objectives and assessments will guide students through engaging tasks. This improves student comprehension and overall learning outcomes.
3. Introducing tangrams gradually helps students become familiar with the tool before tackling more complex tasks. This step-by-step approach ensures students build a strong foundation. It prevents frustration and keeps them engaged throughout the learning process.
4. Collaborative learning in tangram activities encourages peer interaction and problem-solving. Working in groups promotes communication and diverse thinking. This deepens students' understanding of geometric concepts.
5. Teachers need specific training to effectively use tangrams in geometry lessons. Professional development programs will equip them with the skills to engage students. Well-trained teachers can create dynamic, interactive classrooms.
6. Mathematics teachers should be motivated to incorporate tangram activities into their lessons. This improves spatial reasoning and critical thinking in students. Consistent use of tangrams across classrooms benefits student learning.
7. Tangram activities should be included in textbooks to provide regular hands-on learning. This makes it easier for teachers to implement and ensures students practice geometry. It reinforces students' understanding of geometric concepts.

Bibliography

Bohning, G. &Althouse, J. K. (1997). Using Tangram to teach geometry to young Children. *Early Childhood Education Journal*, *24*(4), 239-242.

Cheng, L. (2020). The impact of Tangram puzzles on elementary students' geometric understanding. *Journal of Mathematics Education*, 13(2), 88-99. https://doi.org/10.1007/s10857-019-09434-w

Cheng, Y. (2020). The impact of Tangram-based geometry instruction on elementary students' conceptual understanding. *Journal of Mathematics Education*, *23*(1), 45-60. https://doi.org/10.1007/s10857-019-09434-w

Furner, J. M., & Worrell, N. L. (2017). The importance of using manipulatives in teaching math today. *Transformations*, 3(1), 1-25. https://doi.org/10.14434/transformations.v3i1.24402

Farooq R.A (2001). *Understanding Research in Education*, Rawalpindi; University of Arid Agriculture.

Gutiérrez, A., & Rico, L. (2023). Gender differences in geometric knowledge acquisition. *Gender and Education*, 35(2), 205-220.

Hussain, S., Ahmed, N., & Zafar, M. (2020). The role of Tangrams in enhancing geometry learning in KPK, Pakistan. *International Journal of Educational Research*, 15(3), 130-145.

Hansen, M., & Larson, P. (2010). The effect of dynamic geometry software on students' understanding of geometric knowledge. *Educational Technology & Society*, 13(1), 12-23.

Johnson, D. W., &Ahn, M. J. (2016). Developing geometric knowledge through collaborative learning. *International Journal of Educational Research*, 75, 150-160.

Kaur, M., & Singh, R. (2019). Longitudinal study of geometric knowledge development. *International Journal of Mathematics Education*, 17(1), 100-115.

Liu, X., & Wu, S. (2020). Comparative analysis of Tangram and traditional geometry teaching methods. *Mathematics Education Review*, 12(1), 68-75.

Liu, Q., & Zhang, R. (2020). Developing understanding of translation and rotation through Tangram uzzles. *Journal of Mathematical Education Research*, 19(2), 78-92.

Luo, L., &Zuo, W. (2020). Enhancing geometric understanding and motivation in low-achieving students through Tangram puzzles. *Educational Studies in Mathematics*, *103*(1), 123-140. https://doi.org/10.1007/s10649-019-09924-8

Li, X., & Ma, H. (2019). The role of Tangram in enhancing spatial reasoning in elementary geometry education. *Contemporary Educational Psychology*, 56, 96-105. https://doi.org/10.1016/j.cedpsych.2018.12.002

Li, M., & Ma, X. (2019). Enhancing elementary students' geometric understanding through Tangram puzzles. *Educational Studies in Mathematics*, *101*(2), 231-247. https://doi.org/10.1007/s10649-018-9856-y

Lee, J., & Kim, S. (2016). *Enhancing Spatial Reasoning with Tangram Puzzles: A Van Hiele Perspective*. Journal of Spatial Education, 33(1), 72-85.

Lee, J., & Kim, S. (2016). *Enhancing Spatial Reasoning with Tangram Puzzles: A Van Hiele Perspective*. Journal of Educational Research, 110(5), 497-509.

Lee, K., & Kim, H. (2012). Impact of visual representations on geometric knowledge acquisition. *Journal of Educational Psychology*, 104(2), 300-315.

Lin, C. P., Shao, Y. J., Wong, L. H., Li, Y. J., &Niramitranon, J. (2011). The Impact of Using Synchronous Collaborative Virtual Tangram in Children's Geometric. *Turkish Online Journal of Educational Technology-TOJET*, *10*(2), 250-258.

Nesher, P., &Peled, I. (2021). Evaluating the impact of conceptual vs. procedural instruction on geometric knowledge. *Mathematics Education Research Journal*, 33(3), 567-582.

Nesher, P. (2015). *The Influence of Tangram-Based Activities on Van Hiele Levels of Geometric Understanding*. Journal of Mathematics Education, 10(3), 245-260.

New Jersey Mathematics Curriculum Framework (NJMCF). (1995). *Mathematics curriculum framework for grades preK-12*. Trenton, NJ: New Jersey Department of Education.

Olkun, S., Altun, A., & Smith, G. (2005). Computers and 2D geometric learning of Turkish fourth and fifth graders. *British Journal of Educational Technology*, *36*(2), 317-326.

Sarama, J., & Clements, D. H. (2016). The impact of early mathematics interventions on students' learning trajectories. *Educational Studies in Mathematics*, 93(2), 235-252. https://doi.org/10.1007/s10649-016-9692-3

Sarama, J., & Clements, D. H. (2016). Physical manipulatives versus computer manipulatives in preschool. *Journal for Research in Mathematics Education*, *47*(1), 70-94. https://doi.org/10.5951/jresematheduc.47.1.0070

Sarama, J., & Clements, D. H. (2015). "Supporting young learners' geometric understanding through digital environments." *Early Childhood Research Quarterly*, 30(1), 85-98.

Sweller, J., & Chandler, P. (2014). The influence of cognitive load on learning geometric knowledge. *Cognitive Science*, 38(5), 929-955.

Sarama, J., & Clements, D. H. (2011). Early childhood mathematics education research: Learning trajectories for young children. *Routledge*.

Shroch, S.A. & Coscarelli, W.C. (2007). *Criterion-referenced test development: Technical and legal guidelines for corporate training and certification*. (3rd.ed.).San Francisco, CA: John Wiley&Sons.d

Singh, M., (2004).Modern Teaching of Mathematics.Anmol Publications Pvt Ltd. New Delhi. ISBN: 9788126121052.

Turner, L., & Green, R. (2023). Assessing the role of Tangram puzzles in developing early mathematical concepts. *International Journal of Early Years Education*, *31*(2), 88-103.

Tzuriel, D., &Egozi, G. (2017). Assessing the relationship between spatial ability and geometric knowledge. *Journal of Educational Psychology*, 109(3), 413-426.

Tian, X. (2012). The art and mathematics of tangrams. In *Proceedings of Bridges 2012: Mathematics, Music, Art, Architecture, Culture* . 553-555).

Wang, L., Chen, J., & Zhao, M. (2018). The influence of tangram puzzles on cognitive development and academic performance in primary school children. *Journal of Educational Psychology*, *110*(4), 567-579. https://doi.org/10.1037/edu0000257

Xin, Z. (2018). The role of Tangram puzzles in enhancing elementary students' geometric understanding. *Journal of Mathematics Education*, 13(2), 88-99. https://doi.org/10.1007/s10857-019-09434-w

Yang, J. C., & Chen, S. Y. (2010). Effects of gender differences and spatial abilities within a digital pentominoes game. *Computers & Education*, *55*(3), 1220-1233.

Zhang, Q., & Zhou, Y. (2019). Tangram-based instruction and its impact on students' deductive thinking in geometry. *Journal of Mathematics Education*, 12(3), 157-169. https://doi.org/10.1007/s10857-018-09355-6

Zhang, Y., & Wang, H. (2019). Impact of Tangram puzzles on elementary students' geometric reasoning skills. *Journal of Educational Mathematics*, 11(4), 102-118.

Zhao, N., Wang, X., & Li, H. (2018). The impact of Tangram puzzle teaching on geometric thinking development in elementary students. *Journal of Mathematics Education*, 9(2), 45-56.

Zhang, X., & Wang, H. (2015). Tangram-based instruction and its impact on geometric knowledge and skills. *Journal of Educational Research*, *108*(2), 125-140.