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Developing problem-solving skills in ratios and scales for grade 6 students using cooperative learning with TGT and graphic organizer techniques

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ABSTRACT

This research aimed to develop problem-solving skills in ratios and scale by employing cooperative learning through the Team-Games-Tournaments (TGT) technique in conjunction with the graphic organizer. Students often struggle to understand the relationship between quantities, leading to difficulties in applying ratios and scale accurately. method for sixth-grade elementary school students. The study focused on a target group of 39 sixth-grade students from a medium-sized school in Somdej District, Kalasin Province, during the first semester of the 2024 academic year. The researchers selected participants using purposive random sampling. The research tools included eight lesson plans designed with the TGT technique and graphic organizer methods and a test to evaluate problem-solving skills in ratios and scale. The study adopted an Action Research approach, organized into two action cycles. The first cycle implemented lesson plans 1-4 and included a test featuring five open-ended problems on ratios. Action Cycle 2 utilized lesson plans 5–8 and included a test with five subjective issues on the scale. Statistical tools for data analysis included mean, percentage, and standard deviation. The results indicated that students' problem-solving skills in ratios and scale improved, with an average score of 62.62% in Action Cycle 1 and 74.26% in Action Cycle 2. The second cycle exceeded the 70% criterion with statistical significance at the .50 level.

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1. INTRODUCTION

1.1 Background of the study

Mathematics plays a crucial role in 21st-century education, fostering logical and systematic thinking for problem-solving (Dewanti et al., 2020). It is essential for science, technology, and nation-building, contributing to a dynamic economy (Aguele & Usman, 20007). Mathematics education faces challenges in incorporating new developments, improving teacher professional development, and developing new assessment methods. To meet economic goals, mathematics curricula and teaching methods must be more relevant and application-oriented (Agah, 2020). Widjajanti (2018) recommends humanistic mathematics learning to develop 21st-century skills, treat students as capable individuals, and foster positive relationships. This approach encourages curiosity, critical and creative thinking, problem-solving, collaboration, and positive attitudes toward mathematics (Widjajanti, 2018).

However, current assessments of mathematical competencies in higher education are not sufficiently focused on 21st-century skills (Prachagool & Nuangchalerm, 2021). Mathematics education in Thailand faces significant challenges, as evidenced by consistently low performance in national and international assessments. Thai students particularly struggle with mathematical problem-solving, including the comprehension and transformation of word problems (Prakitipong & Nakamura, 2006). These difficulties are reflected in the 2023 National Basic Education Test (O-NET) results for Grade 6 mathematics, which reported an average national score of 29.96 out of 100—well below the 50% standard (The National Institute of Educational Testing Service (NIETS), 2017).

Similarly, the Trends in International Mathematics and Science Study (TIMSS) 2015, involving 39 countries, ranked Thailand 26th with an average score of 431, placing it in the low-performance range (400-474 points) and significantly below the international average of 500 points (Institute for the Promotion of Teaching Science and Technology, 2016). Research shows a strong positive correlation between reading comprehension skills and mathematics word problem-solving performance, suggesting that improving reading skills could significantly enhance mathematical achievement (Supontawanit & Lertlit, 2021). These challenges are not unique to Thailand. Thai students, despite participating in TIMSS since 1999, consistently score below the international average. While they exhibit proficiency in basic fact recognition, they struggle to apply complex mathematical concepts.

1.2 Explore importance of the problem

The Team-Games-Tournaments (TGT) cooperative learning model has consistently demonstrated positive impacts on mathematics learning outcomes across various educational levels. This model enhances student motivation, engagement, and understanding of mathematical concepts while also fostering social and cooperative skills (Nisa et al., 2024). Studies indicate that TGT is more effective than conventional learning methods (Bolhassan & Taha, 2017) and it is significantly improved students' problem-solving abilities (Puspitasari et al., 2019). Research further reveals that students with high achievement levels demonstrate excellent problem-solving skills when using TGT, while medium-achieving students show good abilities, and low-achieving students exhibit limited problem-solving skills (Puspitasari et al., 2019).

Additionally, the TGT model has been reported to significantly enhance students' learning outcomes, conceptual understanding, and overall effectiveness in mathematics education (Riyanti et al., 2024). Mathematical problem-solving is a critical component of mathematics education, serving as both a foundational skill and a key process in teaching the subject. Effective problem-solving enables learners to develop analytical skills, acquire knowledge, and cultivate desirable characteristics such as persistence, enthusiasm, and confidence. It also promotes diverse thinking and equips students to address challenges within and beyond the classroom (Krulik & Rudnick, 1988).

To strengthen students' mathematical problem-solving abilities, cooperative or team-based learning strategies can be employed to foster collaboration and skill development. One such approach is the Team-Games-Tournaments (TGT) technique, which emphasizes learner-centered activities. In this method, students work in small groups of 4-5 members with diverse skill levels, collaborating to support each other and engage in discussions to achieve a clear understanding of lessons or assigned tasks. The technique incorporates competitive games where teams accumulate scores, fostering both collaboration and individual accountability. High-performing teams are recognized and rewarded, further motivating students (Slavin, 1995).

1.3 Integrating graphic organizers and cooperative learning

The *Four Corner and a Diamond Graphic Organizer*, originally proposed by Zollman (2009) and later refined by Limond (as cited in Morrison Jr., 2012), has been recognized as an effective instructional tool for improving students' comprehension and problem-solving skills. This organizer consists of five interconnected components—Main Idea, Connections, Brainstorm, Solve, and Write—that guide students through a structured thinking process. It helps them document their thought patterns, make connections among concepts, and reflect on their approaches, thereby promoting metacognitive awareness and iterative improvement. When used alongside the Team-Games-Tournaments (TGT) cooperative learning strategy, the impact of this graphic organizer is further amplified. TGT encourages collaborative problem-solving, peer interaction, and formative feedback. Together, these methods foster critical thinking, strategic planning, and effective communication, enabling students to apply mathematical concepts in meaningful and practical ways. This combination of visual structuring and cooperative learning aligns with research advocating for active, student-centered instructional approaches in mathematics education.

Graphic organizers have been shown to enhance students' mathematical problem-solving abilities. Zollman (2009) developed the "Four Corners and a Diamond" graphic organizer, which helps students organize their thoughts, identify relationships between concepts, and improve comprehension and communication skills in mathematics. This tool consists of five sections that guide students through problem analysis, solution planning, and systematic documentation of their approaches. Research has demonstrated the effectiveness of this graphic organizer in improving students' performance in mathematics word problems, particularly for lower-ability students (Mei & Tengah, 2021). Using graphic organizers allows students to sort information, classify it as essential or non-essential, and structure their problem-solving process. Teachers can efficiently diagnose students' abilities by integrating graphic organizers into mathematics instruction and facilitate more effective problem-solving strategies (Zollman, 2009).

1.4 Research objectives

To develop problem-solving skills on ratios and scale using cooperative learning with the Team-Games-Tournaments and graphic organizer technique for 6th-grade students. This objectives leads to the following research questions:

1. To what extent does integrating the TGT cooperative learning technique and the Four Corners and a Diamond Graphic Organizer enhance Grade 6 students' problem-solving skills in ratios and scale?
2. Is there a statistically significant improvement in students' problem-solving performance between Action Cycle 1 and Action Cycle 2?
3. Do students' problem-solving scores in Action Cycle 2 meet or exceed the 70% proficiency benchmark set by the study?

1.5 Theoretical Concepts and Related Research

In this study, the researchers reviewed research findings, theories, concepts, and principles related to cooperative learning using the Teams-Games-Tournaments. TGT is a cooperative learning method developed by Slavin (1987: 23–26) at Johns Hopkins University in the United States. This learning method divides students with varying abilities into groups of approximately 4-5 members to work together. Members of each group compete in educational games prepared by the teacher and participate in knowledge-testing competitions. The scores from these individual competitions, conducted in a one-on-one format against members of other teams, are combined into a team score. The teacher uses reinforcement techniques, such as rewards and verbal praise, to encourage participation.

The TGT cooperative learning process consists of the following five steps: 1. knowledge review 2. team formation 3. teaching and learning 4. competitive games 5. recognition of successful teams additionally, the researcher studied the concept of graphic organizers, specifically the Four Corner and a Diamond Graphic Organizers (Morrison Jr, 2012). This tool aids in developing learners' problem-solving abilities by illustrating the connections between information, encouraging thoughtful problem-solving, and enabling students to articulate their mathematical problem-solving processes rationally. The organizer also allows learners to revise and refine their problem-solving approaches for greater accuracy and efficiency. Students can document their problem-

solving processes in any section of the organizer, which was developed by (Morrison Jr, 2012) and adapted from Zollman's (2009) framework.

The organizer comprises five key components: 1. main idea: a space to document what the problem requires. 2. connections: a space to record information provided in the problem and check if similar problems have been solved before. 3. brainstorm: a space to write strategies and mathematical approaches for solving the problem. 4. solve: a space to document the step-by-step process of solving the problem. 5. write: a space to summarize the solution steps and provide reasoning for the answers. The researchers also developed a conceptual framework for this study, illustrated in Figure 1.

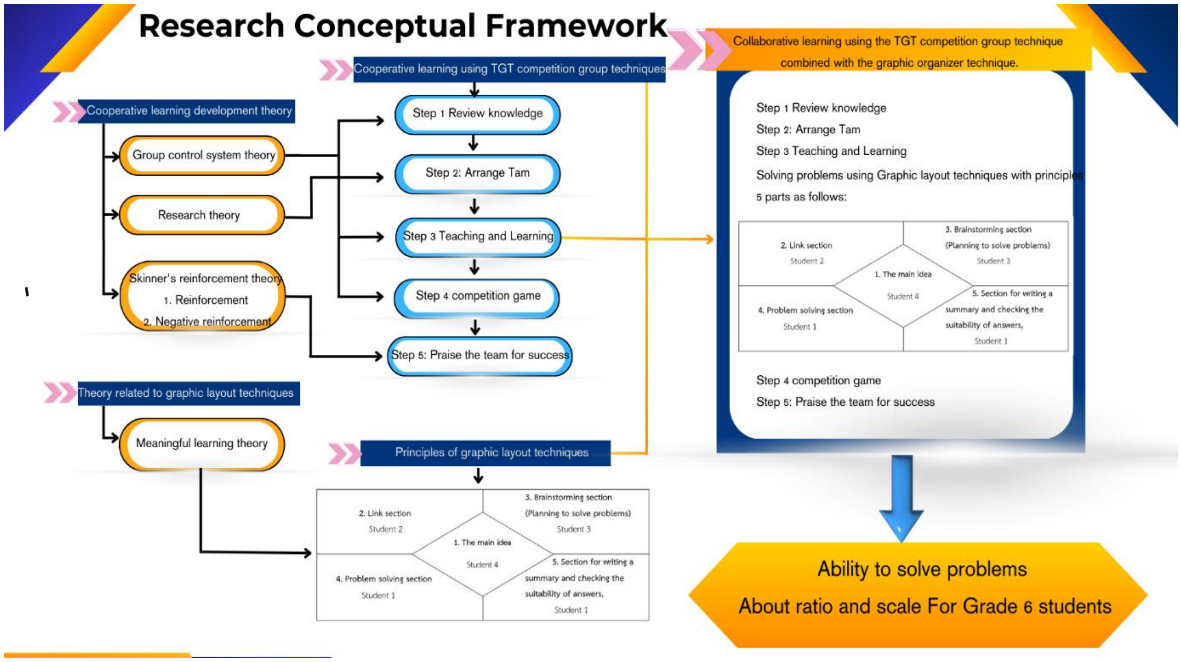

Figure 1 Conceptual framework

2. METHOD

2.1 Research design

The research design followed the Action Research framework proposed by Kemmis & McTaggart (1988), which consists of four procedural steps as follows:

Planning: In this step, the researcher and research assistants collaboratively analyze the current problems in learning activities to determine strategies for planning and improving the teaching and learning process.

Action: This step involves implementing learning activities based on the lesson plans developed during the planning stage.

Observation: This step includes observing changes that occur during the implementation of the learning activities.

Reflection: The data gathered is analyzed collaboratively to identify the root causes of the problems. Discussions are conducted to derive recommendations for enhancing the quality of learning activities in the subsequent action cycles.

2.2 Target group

The study's target group consisted of 39 6th-grade students from a medium-sized school in Somdej District, Kalasin Province, during the first semester of the 2024 academic year. The target group was selected using purposive sampling. This sampling method was chosen to ensure that the participants possessed specific characteristics relevant to the research objectives. Grade 6 students were selected because they were at an appropriate developmental stage for engaging with the instructional strategies being studied, particularly in relation to mathematical problem-solving. Moreover, the selected school was accessible to the researchers and

provided a suitable context for implementing and observing the instructional intervention. Purposive sampling allowed for a focused and practical examination of the effects of the proposed teaching model within a real classroom setting.

2.3 Research instruments

This study employed the following research instruments:

Lesson Plans for teaching mathematics on ratios and scale using cooperative learning with the TGT and graphic organizer technique. Studying the Basic Education Core Curriculum, B.E. 2551 (Revised Edition, B.E. 2560), for the mathematics learning area and existing lesson plans that incorporate the TGT technique with graphic organizers. Drafting 8 lesson plans on ratios and scale, adhering to the structure of cooperative learning with the TGT technique combined with graphic organizers. These lesson plans align with the indicators for each topic and span a total of 8 hours.

Submit the lesson plans to 3 experts for evaluation to ensure alignment, coherence, and comprehensiveness across all components. The assessment used a 5-point Likert scale (Srisa-at, 2010, pp. 82–83) to evaluate the appropriateness of each plan. The evaluation results showed that the mean scores of the plans ranged from 4.37 to 4.72, indicating a high to very high level of appropriateness. The overall mean score was 4.65, signifying a very high level of appropriateness. Problem-solving ability tests on ratios and scale for grade 6 students. The instruments consisted of two subjective test sets, each containing 5 items by the first set focused on problem-solving tasks related to ratios, and the second set addressed problems related to scale. The scoring criteria for the problem-solving ability tests on ratios and scale are detailed in Table 1.

Table 1 Assessment criteria for problem-solving ability on ratios and scale

Item	Assessment criteria
1. Problem understanding	
1.1 Main idea	The learner correctly identifies the information provided in the problem. (1 point)
1.2 Connections	The learner correctly identifies the question asked in the problem. (1 point)
2. Planning the solution	
2.1 Identifying strategies	The learner correctly identifies the strategy to solve the problem. (1 point)
2.2 Providing reasons for strategies	The learner provides correct reasoning for choosing the strategy. (1 point)
2.3 Writing symbolic statements	The learner correctly writes the symbolic statements. (1 point)
3. Solving the problem	
3.1 Step-by-step problem solving	The learner demonstrates the correct steps to solve the problem. (1 point)
3.2 Use of mathematical language	The learner correctly uses mathematical language and symbols. (1 point)
3.3 Calculating the answer	The learner correctly calculates the answer. (1 point)
4. Checking	
4.1 Summarizing	The learner correctly summarizes the required answer. (1 point)
4.2 Validating the answer	The learner correctly validates the appropriateness of the answer. (1 point)
Total	10 points

The quality of the problem-solving ability test on ratios and scale was evaluated by analyzing the expert assessments to calculate the Index of Consistency (IOC) (Zunde & Dexter, 1969) between the test items and the operational definitions. Test items with an IOC value between 0.50 and 1.00 were selected. The results showed that the consistency index for test items in Action Cycle 1 was 0.96, while in Action Cycle 2, it was 0.71. These values indicate that the test items align with the operational definitions and meet the criteria for behavioral validity.

2.4 Data Collection

Action Cycle 1

Step 1: Planning

Observation and Assessment:

Survey and observe the classroom to identify existing issues, as well as study the needs and basic capabilities of grade 6 students during the first semester of the 2024 academic year. Observations were conducted during the teaching and learning activities.

Studying and analyzing the Basic Education Core Curriculum, B.E. 2551 (Revised Edition, B.E. 2017) Ministry of Education (2017) and the expected learning outcomes for mathematics at the target school. Identifying the content to be used in teaching activities and review related theories, concepts, and research to guide the development of research tools.

1. Lesson plans: Develop lesson plans for teaching mathematics on ratios and scale using cooperative learning with the TGT with graphic organizers. A total of 8 lesson plans were created, covering 8 hours across 2 action cycles: Cycle 1: 4 lesson plans. Cycle 2: 4 lesson plans.

2. Problem-solving ability test: Create a subjective problem-solving ability test on ratios and scale for each action cycle. Each test set (Cycle 1 and Cycle 2) consists of 5 situational problems.

Advisor Consultation: Present the developed lesson plans to the thesis advisor for feedback and recommendations. Revise the plans as necessary.

Expert evaluation: Submit the research instruments to three experts to evaluate their alignment, accuracy, and appropriateness concerning the expected learning outcomes.

Instrument revision: Improve and refine the instruments based on the recommendations provided by the experts and the thesis advisor.

Finalization of research instruments: Print the finalized lesson plans, problem-solving ability tests, and mathematical processes to be used with the target group.

Step 2: Action

Implementing the 4 mathematics lesson plans aimed at developing problem-solving skills on ratios and scale among grade 6 students.

Step 3: Observation

Observing the target group during classroom activities by monitoring students' behavior and performance. Reflect on each lesson plan within the action cycle by evaluating students' problem-solving abilities on ratios and scale after completing the learning activities.

Step 4: Reflection

Analyzing the data obtained from the problem-solving ability tests on ratios and scale using the predetermined evaluation criteria. Additionally, review the post-cycle records after completing the action cycle. Use the findings to design and refine the learning activities for Action Cycle 2, ensuring improved quality and effectiveness.

Action Cycle 2

Step 1: Planning

Studying and identifying methods to address the issues identified through the analysis of Action Cycle 1.

Develop mathematics lesson plans to enhance problem-solving skills on ratios and scale. While integrating solutions and strategies to address the issues identified in Action Cycle 1.

Step 2: Action

Implementing the 4 mathematics lesson plans to developing problem-solving skills on ratios and scale.

Step 3: Observation

Observing the target group during classroom activities by monitoring students' behavior and performance. Reflect on each lesson plan within the action cycle by evaluating students' problem-solving abilities on ratios and scale after completing the learning activities.

Step 4: Reflection

Analyzing the data obtained from the problem-solving ability tests on ratios and scale and the post-cycle records. Use the findings to assess the effectiveness of the learning activities and propose further improvements.

2.5 Data Analysis

The analysis of problem-solving ability on ratios and scale using cooperative learning with the TGT with the graphic organizer technique for grade 6 students was conducted using basic statistics, including mean, percentage, and standard deviation. The quality levels of problem-solving ability on ratios and scale were assessed based on the following criteria:

Score 70 and above	Excellent quality level
Score 60-69	Good quality level
Score 50-59	Satisfactory quality level
Score 40-49	Needs improvement quality level

3. RESULT AND DISCUSSION

Action Cycle 1 based on the problem-solving ability test on ratios administered during action cycle 1, the researcher found that the students' average scores were below the 70% threshold. Data analysis from the problem-solving ability tests on ratios and scale, as well as interviews with students, revealed that when cooperative learning using the TGT with graphic organizer technique was implemented in action cycle 1, students' problem-solving abilities on ratios did not meet the 70% benchmark of the total score. the researchers used these findings to design learning activities for action cycle 2 to further enhance students' problem-solving abilities on scale and ensure they met the 70% benchmark of the total score. These results are presented in Table 2.

Table 2 Analysis of problem-solving ability scores on ratios for all students in cycle 1

	Problem-solving ability scores on ratios						
	Main idea (5)	Connections (5)	Brainstorm (15)	Problem-solving (15)	Summary (10)	Total (50)	Percentage (100)
Mean	5	5	8.28	7.92	5.10	31.30	62.62
SD	0	0	2.54	1.98	0.82	-	-
%	100	100	55.21	52.82	51.03	-	-

Action Cycle 2 Based on the data analysis from the problem-solving ability test on scale during Action Cycle 2 (see Table 16), the researcher found that 26 students scored above 70%, while 13 students scored below 70%. The breakdown of students scoring below 70% is as follows: Students 1, 2, 5, 11, 12, 19, and 30 scored 64%. Students 4, 6, 7, and 9 scored 56%. Student 18 scored 66%. Student 22 scored 62%. The analysis of each action cycle indicated that all 13 students demonstrated gradual improvement in their problem-solving ability on scale over time. These results are presented in Table 3.

Table 3 Analysis of problem-solving ability scores on ratios for all students in cycle 2

	Problem-solving ability scores on ratios						
	Main idea (5)	Connections (5)	Brainstorm (15)	Problem-solving (15)	Summary (10)	Total (50)	Percentage (100)
Mean	5.00	5.00	10.00	10.44	6.69	37.13	74.26
SD	0.00	0.00	2.32	2.91	0.47	-	-
%	100.00	100.00	66.67	69.57	66.92	-	-

The development of problem-solving ability on ratios and scale was conducted using cooperative learning with the TGT with the graphic organizer technique for grade 6 students. The goal was to achieve the benchmark of 70% of the total score. The researchers collected data on problem-solving ability on ratios and scale through post-tests administered after implementing the cooperative learning activities with the TGT technique and graphic organizer technique in each action cycle. The students' problem-solving scores on ratios and scale were compared against the 70% benchmark of the total score. The results are presented in Table 4.

Table 4 Total scores of problem-solving ability on ratios and scale

	Action Cycle 1		Action Cycle 2	
	Percentage	Assessment	Percentage	Assessment
Mean	62.62	Fail	74.26	Pass
SD	9.70	-	10.81	-

Table 4**,** it was found that the total scores of problem-solving abilities on ratios and scale, as measured by the problem-solving ability test on ratios and scale, showed an improvement after implementing cooperative learning activities with the TGT with graphic organizer technique. In action cycle 1**,** students achieved an average score of 62.62%. In action cycle 2**,** the average score increased to 74.26%. This indicates that students' problem-solving ability on ratios and scale improved through the implementation of cooperative learning with the TGT technique and graphic organizer technique in each action cycle. Additionally, the average problem-solving ability score surpassed the benchmark of 70% in action cycle 2.

The problem-solving ability on ratios and scale using cooperative learning with the TGT technique and graphic organizer technique for grade 6 students met the 70% benchmark, with 26 students (74.26%) achieving the benchmark at a statistical significance level of .05. The study was conducted over two action cycles, and the results, action cycle 1, in this cycle, learning activities using cooperative learning with the TGT with graphic organizer technique emphasized all components equally. The aim was to observe the development of students' problem-solving ability on ratios and scale. Students achieved an average score of 62.62%.

Action cycle 2, in this cycle, while the same techniques were employed, the researcher focused on specific components, such as brainstorming (planning problem-solving), problem-solving execution, summarizing, and validating answers. These refinements aimed to further enhance students' problem-solving ability. Students achieved an average score of 74.26%, surpassing the 70% benchmark in this cycle. By integrating cooperative learning strategies such as TGT and graphic organizers, you exemplify how well-prepared teachers are, equipped with 21st-century teaching skills. It significantly enhances student learning outcomes, especially in mathematics problem-solving (Poonputta & Nuangchalerm, 2024).

The observed improvement in problem-solving ability can be attributed to the structured approach of cooperative learning with the TGT with graphic organizer technique. The teaching process included the following steps: 1. Reviewing prior knowledge: Students demonstrated their existing understanding of the topic. 2. Team formation: The teacher formed mixed-ability teams comprising high, medium, and low achievers in a 1:2:1 ratio.3. Teaching and learning: The teacher taught the content and provided learning materials for students to collaborate and assist each other. Teams worked together to prepare for competitions while focusing on comprehension. The graphic organizer was used to guide problem-solving with five sections: Main Idea: A space to record what the problem is asking. Connections: A space to document information provided in the problem. Brainstorm: A space to write strategies for solving the problem. Problem-Solving Execution: A space to show step-by-step solutions. Summary: A space to summarize the solution and justify the answer. Competitive games: Teams competed based on their skills, with individuals earning points for their teams. Recognition of successful teams**:** The teacher announced the winning team and awarded prizes and public recognition to the team with the highest score. This structured approach aligns with the research by (Seepiwsiw & Seehamongkon, 2023), which found that cooperative learning with problem-solving processes for Grade 6 students resulted in scores meeting the 70% benchmark. Similarly, (Heebkaew & Seehamongkon, 2024) found that using the STAD technique and KWDL technique exhibited an efficiency of 76.14/75.45, satisfying the 75/75 criterion.

4. CONCLUSION

The findings demonstrated that this approach effectively improved students' problem-solving skills. In action cycle 1, students achieved an average score of 62.62%, indicating initial progress but falling short of the 70% benchmark. The refinements implemented in action cycle 2, which emphasized brainstorming, problem-solving execution, summarizing, and validating answers, led to an average score of 74.26%, surpassing the benchmark and achieving statistical significance at the .05 level. The structured learning process, incorporating review, team formation, collaborative learning, competitive games, and recognition, fostered an engaging and effective environment for developing problem-solving skills. The integration of the graphic organizer technique provided a clear framework for analyzing and solving problems systematically, contributing to the observed

improvement in students' performance. The results align with previous studies, confirming the effectiveness of cooperative learning and graphic organizers in enhancing problem-solving abilities. This approach can be recommended for broader implementation in mathematics education to promote critical thinking, collaboration, and reasoning skills in students. The future research should examine the effectiveness of integrating cooperative learning using the TGT with graphic organizers in developing other cognitive skills, such as analytical thinking and critical thinking. Further studies should also explore the application of this instructional method to other mathematical topics to assess its potential for enhancing problem-solving abilities across various areas of mathematics.

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