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The Effect of Puzzle-Assisted Team Games Tournament on Junior High School Students' Critical Thinking Skills and Cognitive Science Learning Outcomes

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Abstract: This study analyzed the effect of puzzle-assisted Team Games Tournament (TGT) on students' critical-thinking skills and cognitive learning outcomes in science. A quasi-experimental nonequivalent control group design was employed. The population comprised 102 seventh-grade students at SMPN 2 Pringgarata across four classes. Purposive sampling was based on comparable academic characteristics and previous-semester achievement, resulting in Class VII A as the experimental group ($n = 30$) and Class VII B as the control group ($n = 33$). The intervention was implemented in two meetings between October 1 and 14, 2019. The experimental group participated in TGT integrating a colored two-dimensional picture puzzle during team study, games, and tournament activities, whereas the control group received conventional instruction through teacher explanation, question-and-answer activities, and assignments. Data were collected using an instructional implementation observation sheet, five essay items for critical-thinking skills, and 25 multiple-choice items for cognitive learning outcomes. The experimental group's mean critical-thinking score increased from 60 to 90, whereas the control group's mean increased from 55 to 80. The experimental group's mean cognitive score increased from 58 to 76, whereas the control group's mean remained at 54. Independent-samples t-tests on posttest scores indicated significant differences in critical-thinking skills, $t(61) = 4.677$, $p < .001$, $g = 1.17$, and cognitive learning outcomes, $t(61) = 6.502$, $p < .001$, $g = 1.62$. The normalized gain for critical thinking was 0.75 in the experimental group and 0.56 in the control group; the corresponding values for cognitive learning outcomes were 0.43 and 0.00. Students participating in puzzle-assisted TGT achieved higher outcomes than those receiving conventional instruction. The findings should be interpreted cautiously because classes were not randomly assigned and the study was conducted at a single school.

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Introduction

Science education is not limited to the mastery of facts and concepts; it should also engage students in identifying relevant information, analyzing relationships among concepts, evaluating evidence, constructing explanations, and drawing conclusions. These practices are essential for using scientific knowledge to understand phenomena and solve problems in everyday life (National Research Council, 2012). The abilities to interpret, analyze, evaluate, and infer are central components of critical thinking (Facione, 2015). The development of critical thinking also involves metacognitive awareness, strategic regulation, and the coordination of theory and evidence (Kuhn, 1999). In science classrooms, these abilities can be strengthened through discussion, argumentation, and collaborative evaluation of scientific explanations (Osborne, 2010). Consequently, instruction dominated by teacher explanation may restrict students' opportunities to test ideas, justify claims, evaluate evidence, and compare alternative solution strategies.

A preliminary observation conducted at SMPN 2 Pringgarata on September 23, 2018, indicated that integrated science instruction still relied heavily on textbooks, worksheets, lectures, and question-and-answer activities. Teachers and students reported that participation in providing reasons, responding to peers' ideas, and solving problems was uneven. Although the midsemester mean scores of all classes exceeded the Minimum Mastery Criterion of 65, these scores did not fully represent the quality of students' reasoning, their ability to analyze information, or their capacity to justify answers. Therefore, the instructional problem was not defined solely by test completion but also by limited opportunities for analysis, argumentation, and accountable explanation.

One instructional alternative is the cooperative learning model known as Team Games Tournament (TGT). TGT combines class presentation, heterogeneous teams, team study, academic games, tournaments, score calculation, and team recognition (DeVries & Slavin, 1978). Cooperative learning structures can promote positive interdependence, promotive interaction, individual accountability, and collaborative skills (Johnson & Johnson, 2009). Group work is more likely to improve achievement when group goals and individual accountability encourage students to support one another while maintaining personal responsibility for learning (Slavin, 2014). In TGT, games and tournaments provide situations in which students must prepare individually, coordinate with teammates, compare responses, and contribute to team performance.

The puzzle medium complements this structure by providing a visual representation that must be organized into a coherent whole. Combining words and pictures can help learners connect information and construct deeper understanding when visual elements are aligned with instructional goals (Mayer, 2009). The puzzle used in this study consisted of colored, two-dimensional picture pieces representing components of a science concept. Students assembled the pieces, identified relationships among them, discussed the completed representation, and answered questions integrated into the game. Puzzle-based activities have been reported to support students' conceptual organization and active learning (Cardozo et al., 2016). More broadly, evidence from game-based learning research indicates that games can support cognitive learning when their goals, rules, challenges, and feedback are meaningfully integrated with instructional content (Clark et al., 2016). Thus, the puzzle was not merely an entertainment element; it functioned as a medium for observation, information organization, discussion, and problem solving within the TGT sequence.

Although TGT and game-based media have been applied in various instructional contexts, evidence concerning puzzle-assisted TGT in junior high school science while simultaneously assessing critical-thinking skills and cognitive learning outcomes remains limited. The present study addressed two research questions: (1) Do students taught through puzzle-assisted TGT achieve higher critical-thinking scores than students taught through conventional instruction? and (2) Do students taught through puzzle-assisted TGT achieve higher cognitive learning outcomes than students taught through conventional instruction? The hypotheses proposed that the experimental group would obtain higher posttest scores on both outcomes than the control group.

Research Method

Research Design

This study employed a quasi-experimental nonequivalent control group design because the classes had already been formed before the research and individual students could not be randomly assigned (Shadish et al., 2002). Both groups completed a pretest and a posttest. The independent variable was puzzle-assisted TGT, while the dependent variables were critical-thinking skills and cognitive learning outcomes. The learning topic, instructional objectives, implementation period, and assessment formats were held constant; the primary difference was the instructional model and the use of the puzzle medium.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental (VII A)	O_1	Puzzle-assisted TGT	O_2
Control (VII B)	O_1	Conventional instruction	O_2

Population and Sample

The population comprised 102 seventh-grade students at SMPN 2 Pringgarata in the 2019/2020 academic year, distributed across four classes. The sample was selected purposively by considering equivalence in grade level, curriculum, subject, regular schedule, and academic characteristics indicated by previous-semester mean scores. Class VII A was assigned as the experimental group with 30 students, and Class VII B was assigned as the control group with 33 students. Thus, 63 students were included in the analysis.

Instructional Procedure

The study was conducted from October 1 to 14, 2019, with two meetings in each class. Instruction was implemented by the researcher using the prepared lesson plans. Both groups studied the same integrated science content during regular instructional periods. In the experimental group, instruction followed these stages: (1) presentation of learning objectives and key concepts; (2) formation of heterogeneous teams; (3) team study using colored two-dimensional picture puzzles; (4) games involving puzzle assembly and academic questions; (5) a tournament involving students with relatively comparable achievement levels; (6) calculation of individual and team scores; and (7) team recognition and conceptual reinforcement. The control group received teacher explanation, question-and-answer activities, and assignments without the game, tournament, and puzzle structures.

Research Instruments

Instructional implementation was documented using an observation sheet that assessed the alignment of classroom activities with the lesson plan. Critical-thinking skills were measured using five essay questions that required students to explain reasons, analyze information, and formulate conclusions. Responses were scored according to the completeness and accuracy of reasoning and converted to a 0–100 scale. Cognitive learning outcomes were assessed using 25 multiple-choice questions and were also converted to a 0–100 scale. The archived article documentation did not include complete coefficients for validity, reliability, item difficulty, and discrimination; this limitation was considered when interpreting the findings.

Data Analysis

Instructional implementation was summarized as percentages. Learning improvement was described using pretest means, posttest means, and normalized gain (N-gain), calculated as (posttest − pretest)/(100 − pretest). N-gain values were interpreted as high ($g \geq 0.70$), moderate ($0.30 \leq g < 0.70$), and low ($g < 0.30$) (Hake, 1998). Posttest differences were analyzed using independent-samples t-tests at the 5% significance level. Reporting included degrees of freedom, p values, mean differences, 95% confidence intervals, and Hedges' g effect sizes (Lakens, 2013). The p values and effect sizes were recalculated from the recorded t statistics and group sizes. Posttest standard deviations were algebraically reconstructed from the reported t statistics, variance ratios, group sizes, and mean differences. Because the classes were not randomly assigned and individual-level data were unavailable in the archived manuscript, inferential findings were interpreted cautiously.

Result and Discussion

Instructional Implementation

Table 2. Instructional Implementation Results

Group	Meeting 1	Meeting 2	Mean	Category
Experimental	71.42%	78.57%	74.99%	Good
Control	81.81%	90.90%	86.35%	Very good

Instructional implementation increased across meetings in both groups. The experimental group obtained a mean implementation percentage of 74.99%, while the control group obtained 86.35%. The 11.36-percentage-point difference indicates that conventional instruction was implemented more consistently with the lesson plan than puzzle-assisted TGT. This difference should be considered because the new model required more complex management of teams, games, tournaments, and instructional media.

Critical-Thinking Skills

Table 3. Descriptive Results for Critical-Thinking Skills

Group	n	Pretest Mean	Posttest Mean	Change	N-gain	Category
Experimental	30	60	90	+30	0.75	High
Control	33	55	80	+25	0.56	Moderate

Both groups showed descriptive improvement in critical-thinking skills. The experimental group increased by 30 points, while the control group increased by 25 points. The experimental group achieved a high N-gain, whereas the control group achieved a moderate N-gain.

Cognitive Learning Outcomes

Table 4. Descriptive Results for Cognitive Learning Outcomes

Group	n	Pretest Mean	Posttest Mean	Change	N-gain	Category
Experimental	30	58	76	+18	0.43	Moderate
Control	33	54	54	0	0.00	Low

The experimental group's mean cognitive score increased by 18 points, corresponding to a moderate N-gain. In contrast, the control group's mean remained at 54, producing an N-gain of 0.00. During the study period, conventional instruction did not produce an increase in the control group's mean cognitive learning outcome.

Group Differences and Effect Sizes

Table 5. Independent-Samples t-Test Results and Effect Sizes

Outcome	Experimental, M ± SD	Control, M ± SD	Mean Difference	95% CI	t(df)	p	Hedges' g
Critical thinking	90 ± 8.28	80 ± 8.36	10.00	5.72–14.28	4.677 (61)	< .001	1.17
Cognitive outcomes	76 ± 11.37	54 ± 13.06	22.00	15.23–28.77	6.502 (61)	< .001	1.62

Note. Standard deviations were reconstructed from the reported aggregate statistics (n, t, F, and mean difference). Hedges' g values of approximately 0.20, 0.50, and 0.80 are commonly interpreted as small, moderate, and large effects, respectively.

The independent-samples t-test showed that the experimental group achieved a higher critical-thinking posttest score than the control group, $t(61) = 4.677$, $p < .001$. The 10-point mean difference had a 95% confidence interval from 5.72 to 14.28, and Hedges' $g = 1.17$ indicated a large effect. Cognitive learning outcomes also differed significantly, $t(61) = 6.502$, $p < .001$. The 22-point mean difference had a 95% confidence interval from 15.23 to 28.77, with Hedges' $g = 1.62$, also indicating a large effect.

Discussion

The results indicate that students taught through puzzle-assisted TGT achieved higher critical-thinking outcomes than students receiving conventional instruction. This pattern was reflected in the mean improvement, N-gain category, t-test result, and effect size. The TGT structure required students to prepare answers within teams, explain their reasoning, compare ideas, receive feedback, and demonstrate individual accountability during tournaments. These mechanisms are consistent with cooperative-learning theory, which emphasizes positive interdependence, promotive interaction, group goals, and individual accountability as conditions supporting achievement and higher-quality reasoning (DeVries & Slavin, 1978; Johnson & Johnson, 2009; Slavin, 2014).

The puzzle functioned as a visual representation that students had to organize into a meaningful whole. During assembly and explanation, students selected relevant information, tested the compatibility of the pieces, identified relationships, and justified the completed arrangement. Although motivation and boredom were not measured, the combination of visual representation, active manipulation, discussion, and feedback can theoretically support deeper information processing. This interpretation is consistent with evidence that well-designed visual materials and puzzle-based activities can support conceptual organization and active learning (Mayer, 2009; Cardozo et al., 2016).

For cognitive learning outcomes, the experimental group's mean increased from 58 to 76, whereas the control group's mean remained at 54. Repeated engagement with concepts during team study, games, and tournaments may have provided more opportunities for retrieval, practice, peer explanation, and corrective feedback than conventional explanation and assignments. This finding is compatible with early TGT classroom evidence and with broader reviews indicating that appropriately designed game-based learning can produce positive cognitive outcomes (DeVries & Slavin, 1978; Clark et al., 2016).

The control group showed a higher instructional implementation percentage than the experimental group. Therefore, the experimental group's higher outcomes cannot be attributed to better adherence to the lesson plan. Instead, the lower implementation percentage in the experimental group suggests that puzzle-assisted TGT required more complex classroom management, including team formation, distribution of materials, tournament organization, and score calculation. More extensive teacher preparation and repeated implementation may improve procedural consistency.

The findings should nevertheless be interpreted within the limitations of the quasi-experimental design. The intact classes may have differed on unmeasured characteristics, and the posttest comparison did not statistically control pretest differences through ANCOVA because individual-level data were unavailable in the archived manuscript. Accordingly, puzzle-assisted TGT should not be described as the sole cause of the observed differences. The results provide evidence of higher outcomes associated with the intervention in this particular school context.

Conclusion

Seventh-grade students at SMPN 2 Pringgarata who participated in puzzle-assisted TGT achieved higher critical-thinking skills and cognitive science learning outcomes than students who received conventional instruction. The posttest difference was significant for critical-thinking skills, $t(61) = 4.677$, $p < .001$, $g = 1.17$, and cognitive learning outcomes, $t(61) = 6.502$, $p < .001$, $g = 1.62$. Descriptive improvement was also greater in the experimental group, particularly for cognitive learning outcomes. However, because the classes were not randomly assigned, the intervention was brief, and individual-level data were unavailable, the conclusions should be limited to the study sample and context.

Recommendation

1) Science teachers may apply puzzle-assisted TGT to topics that can be represented visually, provided that tournament rules, scoring procedures, time allocation, and team recognition are carefully prepared.
2) Future studies should involve larger samples, multiple schools, and longer intervention periods.
3) Critical-thinking instruments should include a broader set of items, an indicator-based blueprint, an analytical rubric, and complete validity and reliability evidence.
4) Subsequent research should compare TGT without puzzles, puzzle-assisted TGT, and conventional instruction to distinguish the contribution of the instructional model from that of the medium.

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