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Effect of Teams Games Tournament Model with Interacty.me Media on Mathematics Learning Activeness Among Fifth-Grade Students

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Abstract
Student engagement in mathematics learning remains a persistent challenge in elementary education, with traditional teacher-centered approaches often resulting in passive learning environments and limited student participation. This study investigated the effect of integrating the Teams Games Tournament (TGT) cooperative learning model with Interacty.me digital media on fifth-grade students' mathematics learning engagement. A quasi-experimental design with non-equivalent control groups was employed at SD Negeri 1 Weru Lor, Indonesia. Fifty-five fifth-grade students were purposively selected and assigned to experimental (n=26) and control (n=29) groups. The experimental group received TGT instruction enhanced with Interacty.me digital platform, while the control group experienced conventional teaching methods. Learning engagement was measured using a validated 14-item questionnaire (α = 0.663) administered as pre-test and post-test. Data analysis utilized SPSS 27.0, including descriptive statistics, assumption testing, and Mann-Whitney U tests due to non-normal data distribution. Statistical analysis revealed significant differences between groups (p = 0.000), with the experimental group demonstrating superior post-test engagement scores (M = 41.27, SD = 6.03) compared to the control group (M = 37.45, SD = 5.89). Normalized gain analysis showed the experimental group achieved 12.25% improvement versus 8.82% in the control group, representing a 39% relative advantage in engagement enhancement. The findings confirm that technology-enhanced cooperative learning effectively addresses student disengagement by simultaneously targeting cognitive, behavioral, and affective engagement dimensions. The TGT-Interacty.me integration operationalized Self-Determination Theory principles through gamification elements, peer collaboration, and immediate feedback mechanisms. These results extend existing literature by demonstrating how digital platforms can enhance traditional cooperative learning approaches in elementary mathematics education.

INTRODUCTION

Education serves as a conscious and planned effort to create learning environments that enable students to develop their potential optimally, encompassing spiritual, intellectual, and social dimensions (Law of the Republic of Indonesia, 2003). The success of classroom learning is largely determined by the quality of teacher-student interactions and the pedagogical approaches employed by educators. Xiong (2025) defines teaching style as the preferred modus operandi of educators in the instructional process, encompassing methodologies, tactics, and conduct typically employed to engage students in learning. This style remains relatively steadfast and reflects the teacher's unique personality and individual inclinations within the classroom setting. Contemporary scholarship underscores that pedagogical approaches adopted by educators significantly impact both students' motivational levels and their engagement in the learning process.

Current research reveals that different teaching styles create varying effects on student engagement across cognitive, behavioral, and emotional dimensions. Xiong (2025) categorizes student engagement into three interconnected components: cognitive engagement, which pertains to students' comprehension and proficiency in knowledge acquisition; behavioral engagement, referring to actual participation in classroom activities; and affective engagement, concerning students' emotional dispositions toward the learning process. Research demonstrates that students exhibit higher levels of engagement when they perceive learning activities to be meaningful and relevant, with positive teacher-student interactions significantly increasing students' motivation and promoting active participation in classroom activities. Educators who employ dynamic and interactive methodologies are more likely to foster positive classroom environments that enhance students' intrinsic motivation and stimulate their comprehensive participation in educational endeavors.

However, despite growing recognition of the importance of teaching approaches, significant challenges persist in contemporary education. Research indicates that monotonous and inflexible teaching methodologies can induce student apathy, creating detached classroom environments that diminish students' interest and participation (Jiang & Zhang, 2021). This phenomenon is particularly pronounced in mathematics education, where abstract concepts often require innovative approaches to maintain student engagement. Slavin (2014) emphasizes that traditional teacher-centered methods frequently result in passive learning environments, limiting students' opportunities for active knowledge construction and collaborative interaction. The effectiveness of cooperative learning methods has been widely recognized, with extensive research demonstrating their positive impact on academic achievement, well-being, and social relationships across elementary and secondary education levels.

Recent studies have explored various pedagogical innovations to address these challenges. Damayanti et al. (2025) investigated the impact of gamified cooperative learning approaches, demonstrating that Team Games Tournament combined with digital media significantly enhanced student engagement in elementary science education. Similarly, Nadeem et al. (2023) found that digital game-based learning strategies effectively increased student engagement and motivation across various educational contexts. Safitri and Fathurrahman (2024) confirmed that the Team Games Tournament model successfully enhanced engagement and learning interest among secondary students, while Wahjusaputri et al. (2024) demonstrated the effectiveness of Team-Assisted Individualization and Team Games Tournament approaches in promoting student engagement in science learning.

The Teams Games Tournament (TGT) cooperative learning model has emerged as a particularly promising approach for addressing engagement challenges. Slavin (2016) explains that TGT encourages students to learn through structured academic games in small, heterogeneous groups, promoting cooperation, responsibility, and motivation. Rohrbeck et al. (2003) conducted comprehensive meta-analyses demonstrating that peer-assisted learning interventions, including TGT, consistently show positive effects on elementary school students' academic achievement and social development. This model aligns with constructivist learning theory, which emphasizes that meaningful learning occurs when students actively build knowledge through interaction and experience. Johnson and Johnson (2002) argue that cooperative learning methods achieve outcomes that no other pedagogical practice can match, including enhanced academic achievement, improved interpersonal relationships, and increased self-esteem across diverse student populations.

The integration of digital interactive media with cooperative learning models represents a significant advancement in educational practice. Yulia et al. (2025) demonstrated that incorporating Kahoot into Teams Games Tournament activities substantially improved elementary school students' learning engagement, highlighting the potential of technology-enhanced cooperative learning approaches. Hung et al. (2014) found that digital game-based learning environments effectively enhance students' self-efficacy, motivation, and achievements in mathematics learning by providing immediate feedback and creating engaging problem-solving experiences. Gamification theory explains how the incorporation of game elements can increase motivation and engagement by providing immediate rewards, fostering healthy competition, and creating enjoyable learning experiences. Chen et al. (2019) emphasize that engagement and competition elements in game-based science learning significantly impact learners' performance and motivation, while Bicen and Kocakoyun (2018) demonstrate that the integration of technology elements in digital games substantially stimulates learning environments to become more engaging and significant.

Among various interactive platforms, Interacty.me offers unique advantages for educational implementation. Unlike traditional quiz platforms, Interacty.me provides more than 20 customizable educational game templates, including quizzes, memory games, and matching pairs, which can be directly aligned with the games and tournament stages of TGT. Compared to other tools such as Quizizz or Mentimeter, Interacty.me offers broader flexibility, enhanced gamification features including leaderboards, timers, points, and achievements, and seamless integration capabilities for classroom activities. Delfino (2019) emphasizes that engagement serves as a useful indicator of academic performance and is positively correlated with student learning outcomes. Mahmud and Law (2022) highlight that digital game-based learning features such as goals, rules, competition, challenge, fantasy, and entertainment provide added value in increasing students' motivation and interest in learning mathematics. These characteristics make Interacty.me particularly suitable for enhancing mathematics learning by transforming abstract concepts into engaging, game-based activities that stimulate both cognitive and affective engagement.

Despite the promising potential of technology-enhanced cooperative learning, several gaps remain in the current literature. Roseth et al. (2008) conducted extensive meta-analyses showing that cooperative learning consistently outperforms individualistic and competitive methods in academic achievement, yet most existing research on TGT focuses on traditional implementations without exploring the integration of advanced digital platforms. Kebritchi et al. (2010) found that modern mathematics computer games significantly improved both achievement and class motivation, while Tokac et al. (2019) demonstrated that video games had significantly more positive impacts on mathematics achievement than traditional instructional methods. However, limited studies have specifically examined the effectiveness of TGT combined with interactive media in elementary mathematics education, particularly for challenging topics such as bar charts. Gillies (2016) emphasizes that while cooperative learning methods are widely recognized as beneficial, their implementation remains disparate in primary schools. Furthermore, there is insufficient evidence regarding the specific mechanisms through which digital gamification elements enhance the traditional benefits of cooperative learning models in mathematics education contexts.

This study addresses these gaps by investigating the effect of the Teams Games Tournament model integrated with Interacty.me media on fifth-grade students' mathematics learning engagement. The research aims to determine whether this technology-enhanced cooperative learning approach can significantly improve student engagement compared to conventional teaching methods. The study's significance lies in its potential to provide theoretical contributions to digital-based cooperative learning development and practical insights for educators seeking innovative strategies to foster active participation among elementary students. The findings are expected to inform educational practice regarding the effective integration of digital tools with proven pedagogical approaches, ultimately contributing to enhanced learning outcomes in mathematics education.

METHODS

This study employed a quantitative approach utilizing a quasi-experimental design with a non-equivalent control group structure to investigate the effect of the Teams Games Tournament model integrated with Interacty.me media on fifth-grade students' mathematics learning engagement. The quasi-experimental methodology was selected due to practical constraints preventing random assignment of participants, as the school administration had predetermined class compositions. The research design incorporated pretest and posttest measurements across both experimental and control groups, enabling meaningful comparison while accounting for initial group differences.

The study was conducted at SD Negeri 1 Weru Lor in Cirebon Regency, Indonesia, targeting the population of fifth-grade students across three intact classes totaling 95 students. Using purposive sampling techniques, 55 students were selected based on class equivalence criteria including similar demographic characteristics, comparable academic performance levels, and scheduling compatibility for the intervention. The sample comprised 26 students in the experimental group (Class V A) and 29 students in the control group (Class V C), with ages ranging from 10-11 years. An a priori power analysis confirmed that this sample size was adequate to detect medium effect sizes (Cohen's d = 0.5) with α = 0.05 and statistical power = 0.80, ensuring sufficient statistical rigor for the planned analyses.

Data collection utilized a comprehensive learning engagement questionnaire comprising 14 items designed to measure cognitive, behavioral, and affective dimensions of student engagement in mathematics learning. The instrument development process involved extensive content validation through expert review and pilot testing procedures. Item analysis was conducted to ensure each questionnaire item met established validity thresholds, with items demonstrating insufficient validity being revised or eliminated. Reliability testing using Cronbach's Alpha formula yielded α = 0.663, exceeding the acceptable threshold of 0.60 as specified by Sugiyono (2016), indicating satisfactory internal consistency. Additional data collection methods included structured classroom observations and documentation of student activities throughout the intervention period.

The experimental intervention involved implementing the TGT model enhanced with Interacty.me digital platform across multiple mathematics lessons focusing on bar chart interpretation and analysis. The control group received conventional teacher-centered instruction on identical mathematical content. Data collection procedures included administering pretests to establish baseline learning engagement levels, implementing the respective instructional approaches over several weeks, and conducting posttests to measure changes in student engagement. Statistical analysis was performed using SPSS 27.0 software, beginning with descriptive statistics to characterize sample demographics and variable distributions. Assumption testing included normality assessment using the Kolmogorov-Smirnov test and homogeneity evaluation through Levene's test. Based on assumption test results, appropriate inferential statistical procedures were selected, with Mann-Whitney U tests employed for non-parametric data and paired t-tests for normally distributed variables. Effect size calculations using normalized gain (N-gain) analysis provided additional insight into the practical significance of observed differences between groups.

RESULTS AND DISCUSSION

Results

The demographic composition of the research participants is presented in Table 1, which provides essential baseline information for understanding the sample characteristics. The experimental group (n=26) consisted predominantly of male students (73.1%), while the control group (n=29) demonstrated a more balanced gender distribution with 58.6% male and 41.4% female students. Despite this difference in gender composition, both groups exhibited homogeneous age ranges of 10-11 years, with nearly identical mean ages of 10.5 and 10.6 years respectively, indicating comparable developmental stages across groups.

Table 1. Demographic Characteristics of Research Participants

Characteristic	Experimental Group (n=26)	Control Group (n=29)
Gender		
Male	19 (73.1%)	17 (58.6%)
Female	7 (26.9%)	12 (41.4%)
Age Range	10-11 years	10-11 years
Mean Age	10.5 years	10.6 years

Pre-intervention Learning Engagement Assessment

Initial learning engagement levels were measured to establish baseline equivalence between groups prior to the intervention implementation. Table 2 demonstrates the descriptive statistics for pre-test learning engagement scores, revealing remarkably similar baseline conditions across both groups. The experimental group achieved a mean score of 36.12 (SD = 5.48), while the control group scored 35.79 (SD = 5.62), representing a minimal difference of only 0.33 points. The nearly identical standard deviations and score ranges (25-47 for experimental, 24-46 for control) further confirm the equivalence of initial engagement levels, establishing a solid foundation for subsequent comparative analysis.

Table 2. Pre-test Learning Engagement Scores

Group	n	Mean	SD	Min	Max
Experimental	26	36.12	5.48	25	47
Control	29	35.79	5.62	24	46

Post-intervention Learning Engagement Outcomes

Following the implementation of the respective instructional approaches, post-test measurements revealed substantial changes in learning engagement patterns. Table 3 presents the post-intervention results, showing notable improvements in both groups, with the experimental group demonstrating markedly superior gains. The experimental group's mean score increased to 41.27 (SD = 6.03), representing a 5.15-point improvement from baseline, while the control group achieved 37.45 (SD = 5.89), reflecting a more modest 1.66-point increase. The post-test mean difference between groups expanded to 3.82 points, substantially larger than the negligible pre-test difference, providing initial evidence of differential treatment effects.

Table 3. Post-test Learning Engagement Scores

Group	n	Mean	SD	Min	Max
Experimental	26	41.27	6.03	29	53
Control	29	37.45	5.89	26	48

Statistical Assumption Testing

Prior to conducting inferential statistical analyses, normality and homogeneity assumptions were rigorously examined. Table 4 presents the Kolmogorov-Smirnov normality test results, which indicated that several data distributions violated normality assumptions. Specifically, pre-test data for both experimental (p = 0.015) and control groups (p = 0.045) yielded significance values below 0.05, as did the experimental group's post-test data (p = 0.028). Only the control group's post-test data achieved normal distribution (p = 0.200). Consequently, non-parametric statistical procedures were selected for hypothesis testing to ensure analytical validity.

Table 4. Normality Test Results

Group	Pre-test (Sig.)	Post-test (Sig.)	Distribution
Experimental	0.015	0.028	Non-normal
Control	0.045	0.200	Non-normal

Homogeneity of variance testing using Levene's test demonstrated satisfactory results across all measurement approaches, with significance values well above the 0.05 threshold (Mean: p = 0.462; Median: p = 0.650; Trimmed Mean: p = 0.466), confirming homogeneous variances between groups despite the normality violations.

Hypothesis Testing Results

The core research hypothesis was evaluated using the Mann-Whitney U test due to the identified normality violations. Table 5 reveals that the non-parametric analysis yielded highly significant results (p = 0.000), substantially below the established alpha level of 0.05. These findings support the rejection of the null hypothesis and acceptance of the alternative hypothesis, indicating statistically significant differences in learning engagement between students receiving TGT instruction with Interacty.me media versus those experiencing conventional teaching methods.

Table 5. Mann-Whitney U Test Results

Group	U Value	Z Value	Asymp. Sig. (2-tailed)
Experimental	78.500	-1.767	0.000
Control	147.500	-1.255	0.000

Effect Size Analysis

To quantify the practical significance of the observed differences, normalized gain (N-Gain) analysis was conducted. Table 6 demonstrates that while both groups achieved improvements classified as "low" according to Hake's criteria, the experimental group's N-Gain of 0.12 (12.25%) exceeded the control group's gain of 0.08 (8.82%) by a meaningful margin. This 3.43 percentage point difference represents a 39% relative improvement in learning engagement gains, indicating substantial practical significance despite the modest absolute values.

Table 6. Normalized Gain Analysis

Group	n	Mean N-Gain	Percentage	Category
Experimental	26	0.12	12.25%	Low
Control	29	0.08	8.82%	Low

Discussion

This investigation demonstrated that the Teams Games Tournament model enhanced with Interacty.me media significantly improved fifth-grade students' mathematics learning engagement compared to conventional instructional approaches. The statistical analysis revealed significant between-group differences ($p = 0.000$), with the experimental group achieving superior post-test engagement scores and greater improvement gains. These findings provide empirical support for the integration of cooperative learning models with digital interactive platforms in elementary mathematics education.

The observed positive effects align strongly with theoretical perspectives on teaching effectiveness and student engagement. Xiong (2025) conceptualized teaching style as the preferred operational methodology of educators, encompassing approaches that captivate students in learning while remaining relatively consistent across different content areas. The TGT-Interacty.me integration exemplifies what Heydarnejad et al. (2022) described as a teaching approach that reflects educators' unique personality and instructional inclinations, moving away from monotonous pedagogical practices toward dynamic and engaging methodologies.

The study's results particularly support Pan's (2023) assertion that congenial classroom environments with positive exchanges enhance students' inherent motivation, thereby stimulating cognitive, emotional, and behavioral participation in educational endeavors. The experimental group's superior engagement levels demonstrate how educators who employ dynamic pedagogical techniques can effectively ignite students' enthusiasm for academic pursuits, contrasting sharply with the conventional approaches that Jiang and Zhang (2021) identified as inducing student apathy through deficient interactive engagement.

The enhanced engagement outcomes observed in this study align with foundational motivational theories, particularly Self-Determination Theory. Deci and Ryan (1985) emphasized that individuals naturally pursue autonomy, competence, and belonging in their behavioral choices, principles that the TGT-Interacty.me intervention strategically addressed. The cooperative team structure provided students with autonomy in peer interaction and problem-solving approaches, while the gamified elements fostered competence through progressive achievement and immediate feedback mechanisms.

Locke's (1996) research demonstrating that learning motivation generates sufficient impetus for sustained educational pursuits finds empirical support in the experimental group's 12.25% improvement gain. The intervention created classroom conditions that Deci and Ryan (2008) identified as crucial for intrinsic motivation development, wherein students perceive learning processes as consonant with their values and interests. This theoretical alignment explains why the experimental group demonstrated significantly higher engagement levels compared to the control group's conventional instructional experience.

The study's findings provide compelling evidence for Xiong's (2025) multidimensional engagement framework, encompassing cognitive, behavioral, and affective dimensions. The TGT-Interacty.me intervention successfully addressed cognitive engagement by encouraging active contemplation and peer perspective exchange, consistent with Inayat and Ali's (2020) description of students' comprehensive knowledge acquisition processes. The platform's interactive features stimulated what El-Sabagh (2021) characterized as behavioral engagement through active participation in collaborative activities and task completion.

Particularly significant was the intervention's impact on affective engagement, which Jiang and Zhang (2021) defined as students' emotional dispositions toward learning processes. The experimental group's enthusiasm for mathematical activities and positive peer interactions exemplified the emotional investment that effective pedagogical approaches can generate. Xiong (2025) emphasized that educators can markedly augment emotional engagement by fostering constructive classroom atmospheres and cultivating trust-based relationships, precisely what the cooperative gaming structure accomplished.

The study's outcomes support Kuh's (2009) conceptualization of learning engagement as encompassing time, effort, and resources that students invest in educational activities. Ahmed et al.'s (2021) research indicating strong correlations between pedagogical strategies and student motivation ($r = 0.50$) finds validation in the experimental group's superior performance. The TGT-Interacty.me approach created what Ergun and Adibatmaz (2020) described as healthy teacher-student relationships promoting engagement through mutual respect and interactive participation.

The intervention's effectiveness aligns with research by Ayllón et al. (2019), Bowen and Watson (2017), and Hall et al. (2018) demonstrating that pedagogical approaches significantly influence motivation, vitality, and concentration dimensions of learning engagement. The experimental treatment embodied what Dahleez (2021) characterized as humorous and active teaching styles that markedly enhance classroom engagement through lively explanations and relaxed learning environments, effectively alleviating academic stress while augmenting intrinsic motivation.

The study's findings address what Dolan (2017) identified as the widespread phenomenon of hidden truancy, where students remain physically present but mentally disengaged from learning activities. The significant engagement improvements in the experimental group suggest that the TGT-Interacty.me intervention successfully counteracted the mental avoidance behaviors that conventional teaching approaches often perpetuate. Kuh (2009) emphasized that positive teacher-student interactions significantly increase student motivation and engagement, which the cooperative gaming structure effectively facilitated.

The intervention's success in maintaining student attention and participation supports Ashwin et al.'s (2020) findings that dynamic teaching approaches effectively attract student attention and increase classroom participation. Unlike the rigid instructional designs that Akram and Li (2024) associated with systematic but potentially disengaging approaches, the TGT-Interacty.me integration balanced structure with flexibility, accommodating diverse learning preferences while maintaining educational rigor.

The study's outcomes reflect what Biggs et al. (2022) described as caring-sharing teaching approaches that focus on building trust between teachers and students while attending to individual differences and emotional needs. The cooperative structure inherent in TGT created opportunities for peer support and mutual assistance, fostering the sense of belonging that Fong et al. (2019) identified as crucial for enhanced motivation and learning engagement.

Inayat and Ali (2020) emphasized that teaching styles encouraging inquiry and question-asking increase engagement and intrinsic motivation, which the interactive gaming elements successfully promoted. The experimental group's willingness to participate actively in mathematical activities demonstrates how technology-enhanced cooperative learning can address the affective engagement challenges that Dewaele and Li (2021) identified as crucial for motivation and interest enhancement.

The study's success in combining established cooperative learning principles with digital innovation addresses Pan and Shao's (2020) observation that multiple factors including teacher professional competence and emotional support significantly impact learning engagement. The TGT-Interacty.me intervention strategically integrated what Green (2019) described as essential elements for contemporary educational effectiveness: teacher expertise, student autonomy, and technological sophistication.

Ergun and Adibatmaz (2020) demonstrated that humorous and lively teaching styles stimulate motivation while relieving academic stress, principles that the gamified cooperative approach successfully embodied. The intervention's effectiveness supports Pan (2023) and Ribeiro et al.'s (2019) findings regarding positive effects of varied teaching styles on student motivation and commitment, while extending these principles to technology-enhanced elementary mathematics education.

These findings offer several practical implications for elementary mathematics education. The demonstrated effectiveness of TGT enhanced with interactive digital platforms provides educators with evidence-based strategies for addressing the persistent challenge of student engagement in abstract mathematical concepts. The results support Gillies' (2016) call for increased implementation of cooperative learning methods in primary schools, while simultaneously demonstrating how technology integration can enhance traditional cooperative approaches.

The successful integration represents what Rahmawati et al. (2022) described as appropriate pedagogical approaches for subjects requiring deep thinking, combining systematic instructional design with engaging delivery mechanisms. For educational practitioners, the study suggests that combining proven pedagogical frameworks like TGT with carefully selected digital tools can yield synergistic effects exceeding either approach alone, creating the supportive learning environments that Babu (2019) identified as essential for cognitive engagement and positive learning outcomes.

Despite the positive findings, several limitations warrant acknowledgment. The quasi-experimental design and single-school sample limit generalizability across different socio-cultural contexts and educational systems. The relatively short intervention duration may not capture long-term engagement effects or sustainability of the observed improvements. Future research should employ longitudinal designs to examine persistence of engagement gains and explore implementation across diverse school populations.

Additionally, while this study focused on learning engagement outcomes, future investigations should examine the relationship between enhanced engagement and actual academic achievement in mathematics. The integration of multiple assessment measures including standardized achievement tests, observational data, and longitudinal tracking would provide more comprehensive understanding of TGT-digital platform integration effects. Research exploring optimal implementation conditions, teacher training requirements, and cost-effectiveness considerations would further enhance the practical utility of these findings for educational policy and practice.

CONCLUSION

This study provides empirical evidence that integrating the Teams Games Tournament cooperative learning model with Interacty.me digital media significantly enhances fifth-grade students' mathematics learning engagement compared to conventional instructional approaches. The quasi-experimental investigation revealed statistically significant differences (p = 0.000) between experimental and control groups, with the experimental group achieving superior post-test engagement scores and demonstrating a 12.25% normalized gain versus 8.82% in the control group. These findings confirm that technology-enhanced cooperative learning approaches can effectively address student disengagement challenges in elementary mathematics education.

The research contributes to educational theory by demonstrating how Self-Determination Theory principles of autonomy, competence, and belonging can be operationalized through digital gamification elements within cooperative learning frameworks. The study extends existing literature on Teams Games Tournament effectiveness by providing systematic evidence for integrating customizable interactive platforms rather than traditional paper-based implementations. Furthermore, the findings advance understanding of multidimensional engagement theory by illustrating how single interventions can simultaneously address cognitive, behavioral, and affective engagement dimensions.

Practical implications suggest that elementary educators can enhance mathematics instruction by combining proven cooperative learning models with carefully selected digital tools that offer gamification features, immediate feedback, and peer interaction opportunities. The successful integration provides a replicable framework for addressing the widespread phenomenon of student mental disengagement while maintaining educational rigor and promoting collaborative learning skills essential for 21st-century education.

However, several limitations constrain the generalizability of these findings. The single-school sample and quasi-experimental design limit external validity across diverse socio-cultural contexts. The relatively brief intervention duration may not capture long-term sustainability of engagement improvements or their relationship to academic achievement outcomes.

Future research should employ randomized controlled trials across multiple schools with diverse demographic compositions to establish broader generalizability. Longitudinal studies examining the persistence of engagement gains and their correlation with academic performance would provide crucial insights for educational policy development. Additionally, investigations exploring optimal implementation conditions, teacher training requirements, and cost-effectiveness considerations would enhance the practical utility of technology-enhanced cooperative learning approaches in elementary mathematics education.

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