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Collaborative Learning Models and Their Effect on Student Engagement and Learning Outcomes

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Abstract

This study examined the effects of structured collaborative learning on student engagement and learning outcomes in secondary education using an empirical quasi-experimental design with a non-equivalent control group. Participants were purposively recruited from one school and allocated at the class level to either an experimental group receiving cooperative learning with defined roles, peer-regulation prompts, and task interdependence, or a comparison group receiving teacher-directed instruction. Data were collected through standardized pre-test and post-test achievement measures, structured classroom observations, and a multidimensional engagement questionnaire assessing behavioral, emotional, and cognitive engagement. ANCOVA results indicated that the experimental group achieved significantly higher adjusted post-test scores after controlling for baseline differences. Engagement analyses showed greater gains across all engagement dimensions in the experimental condition, with the strongest improvement in cognitive engagement. Regression-based modeling revealed that cognitive engagement was the most powerful predictor of post-test achievement, followed by behavioral engagement, while emotional engagement showed a weaker direct association under statistical control. The findings demonstrate that structured collaboration enhances learning by strengthening metacognitive regulation and sustained cognitive investment.

Keywords : *Collaborative Learning, Student Engagement, Learning Outcomes, Quasi-Experimental Design, Metacognitive Regulation.*

INTRODUCTION

Across contemporary education systems, collaborative learning has moved from being framed as an optional pedagogical enrichment to being positioned as a structural response to the changing demands of learning in digitally mediated, competency-oriented, and socially distributed knowledge environments. This shift has been intensified by the post-pandemic normalization of technology-supported learning, where interaction is no longer confined to the physical classroom but is increasingly enacted through platforms, social media, and computer-supported collaborative learning (CSCL) environments that reshape how engagement and achievement are produced. The international literature increasingly treats student engagement not merely as a behavioral indicator of participation, but as a multidimensional construct that includes cognitive investment, emotional involvement, and agentic contribution, making collaborative learning models especially relevant because they are designed to activate all dimensions simultaneously rather than privileging surface participation. Within this landscape, engagement is no longer interpreted as an outcome that follows learning, but as a generative mechanism that mediates learning processes and performance trajectories, particularly in contexts where interactional quality determines whether technology amplifies learning or merely digitizes disengagement (Martin & Borup, 2022). The growing reliance on digital learning ecosystems also highlights the need to interrogate how learners accept, appropriate, and sustain educational technologies as part of collaborative activity, since engagement in collaborative learning is increasingly contingent

on perceived usefulness, ease of use, and social influence embedded in the platform itself (Alismaiel et al., 2022).

Prior research has consistently indicated that collaborative and cooperative learning models can positively influence student engagement and learning outcomes, yet the mechanisms through which such effects emerge appear more complex than early effectiveness-oriented studies suggested. Studies grounded in cooperative learning traditions report that structured interdependence and guided peer interaction can strengthen academic goals and performance, particularly when tasks require shared responsibility and meaningful negotiation of understanding (Mendo-Lázaro et al., 2022). At the same time, more recent work suggests that the effectiveness of collaboration is not reducible to grouping students, but depends on the presence of cognitive scaffolds, regulation supports, and task designs that transform peer interaction into learning-relevant discourse. Evidence from CSCL research demonstrates that students' regulation profiles—how they plan, monitor, and evaluate learning together—are differentially associated with performance, motivation, and self-efficacy, implying that collaboration can either enhance or undermine outcomes depending on the regulatory architecture of the group process (De Backer et al., 2022). Complementary findings show that shared metacognitive regulation performs distinct functions that relate unevenly to learners' conceptual understanding, suggesting that collaboration becomes academically productive when groups regulate not only participation but also epistemic quality (De Backer, Van Keer, & Valcke, 2022). This complexity is also reflected in blended models integrating inquiry-based learning with CSCL in flipped classrooms, where improved performance is attributed to the alignment between collaborative inquiry structures and the sequencing of learning activities rather than to collaboration alone (Adhami & Taghizadeh, 2024).

Despite the strong consensus that collaborative learning can be beneficial, the literature still contains conceptual and empirical inconsistencies that limit the generalizability and explanatory power of existing findings. One limitation is the persistent tendency to treat "collaborative learning" as a homogeneous intervention, while empirical evidence indicates that different models (e.g., articulation-based cooperative learning, inquiry-oriented CSCL, or social media collaboration) involve distinct interactional rules, regulation demands, and motivational affordances that can yield divergent effects. For instance, research in elementary contexts shows that articulation-type cooperative learning can improve learning outcomes, yet the transferability of such findings to secondary or higher education remains theoretically underdeveloped because articulation structures may not scale similarly when tasks require higher-order reasoning and self-directed regulation (Indrawati & Desky, 2024). Another gap concerns the inconsistent operationalization of engagement, where studies sometimes collapse engagement into participation metrics, while others conceptualize it as a dynamic psychological state, making cross-study synthesis fragile even when effects appear directionally consistent (Martin & Borup, 2022). Technology-mediated collaborative learning further complicates interpretation because performance gains are often attributed to collaboration, while the underlying driver may be platform acceptance, communication intensity, or self-efficacy differences that moderate the relationship between collaboration and achievement (Liu et al., 2022). These limitations collectively indicate that the field has not fully resolved whether collaborative learning models influence outcomes primarily through interaction structure, regulation processes, motivational mechanisms, or technology acceptance dynamics.

The unresolved issues in this literature are not merely theoretical, since education systems increasingly adopt collaborative learning as a policy-level strategy to enhance engagement and learning outcomes, often without sufficient attention to the conditions under which collaboration becomes cognitively productive. In practice, teachers are frequently expected to implement cooperative learning approaches, yet evidence suggests that professional and pedagogical competencies significantly shape whether cooperative learning is enacted as a meaningful learning design or devolves into unstructured group work that produces unequal participation and superficial engagement. Research in science education indicates that teacher competence affects both the fidelity of cooperative learning implementation and the extent to which engagement and outcomes improve, implying that collaborative learning effectiveness is partially contingent on instructional expertise rather than being inherent in the model itself (Geletu, 2022). The broader movement toward student-centered learning reinforces this urgency, since student-centered tools are frequently promoted as cognitive enhancement strategies, yet their effectiveness depends on how well they orchestrate learners' cognitive activity and interaction rather than simply shifting responsibility to students (Dada et al., 2023). In technology-rich

environments, collaborative learning is also increasingly enacted through social media and digital platforms, which introduces additional layers of variability related to learner attitudes, perceived usefulness, and behavioral intention, all of which can shape engagement trajectories and ultimately learning outcomes (Alismaiel et al., 2022). Without clarifying the mechanisms and boundary conditions of collaborative learning models, institutions risk implementing popular pedagogical reforms that produce inconsistent results, widening achievement gaps and generating teacher skepticism toward evidence-based innovations.

Within this evolving scholarly terrain, the present research positions collaborative learning models not as a single intervention category but as pedagogical systems whose effects depend on the interaction between task structure, regulation processes, motivational resources, and the digital ecology in which collaboration occurs. This positioning aligns with contemporary CSCL perspectives emphasizing that collaboration must be analyzed through learners' regulation profiles and shared metacognitive processes rather than through simplistic exposure-based comparisons (De Backer et al., 2022; De Backer, Van Keer, & Valcke, 2022). It also draws on evidence that collaborative learning gains are strengthened when collaboration is embedded in inquiry-based and flipped learning sequences that redistribute cognitive work across pre-class and in-class phases, allowing peer interaction to operate at higher epistemic levels (Adhami & Taghizadeh, 2024). At the same time, the study acknowledges that collaborative learning increasingly occurs in social media contexts where academic self-efficacy moderates performance outcomes, implying that psychological and technological factors must be integrated into explanatory models rather than treated as peripheral variables (Liu et al., 2022). By synthesizing cooperative learning evidence on goal orientation and structured interdependence with student-centered learning perspectives on cognitive enhancement, the study situates itself at the intersection of learning design, engagement theory, and performance outcomes (Mendo-Lázaro et al., 2022; Dada et al., 2023). This conceptual stance enables the research to contribute to a more discriminating understanding of collaborative learning effectiveness across contexts, rather than reproducing general claims that collaboration is uniformly beneficial.

This study aims to examine the effects of collaborative learning models on student engagement and learning outcomes while clarifying the mechanisms and conditions that explain why some collaborative designs generate sustained engagement and measurable achievement gains whereas others produce weak or inconsistent effects. The research contributes theoretically by refining the conceptual linkage between collaborative learning structures, engagement as a multidimensional mediator, and learning outcomes as both cognitive and performance-based indicators. It contributes methodologically by operationalizing collaborative learning models in a way that distinguishes between interaction structure, regulation supports, and the digital context of collaboration, allowing effects to be interpreted as design-dependent rather than merely model-dependent. The study also provides an empirically grounded framework for educators to select and implement collaborative learning models with greater precision, emphasizing the instructional and contextual factors that must be present for collaboration to function as a learning mechanism rather than as a procedural classroom activity. Through this approach, the research advances a more explanatory and design-sensitive understanding of collaborative learning that can support both scholarly debate and practical decision-making in contemporary education systems.

RESEARCH METHODS

This study employed an empirical approach, as it required observable evidence to examine the relationship between collaborative learning models, student engagement, and learning outcomes. A quasi-experimental design with a non-equivalent control group was implemented in a formal school setting, involving students from the same grade level who were assigned to either an experimental group receiving structured collaborative learning (e.g., cooperative learning with defined roles, peer-regulation prompts, and task interdependence) or a comparison group receiving conventional teacher-directed instruction. Participants were recruited from one secondary school using purposive sampling to ensure comparable curricular exposure and instructional conditions, followed by class-level allocation to minimize disruption to school routines. Data were collected through a combination of pre-test and post-test achievement measures, structured classroom observations to capture behavioral engagement, and self-report questionnaires assessing cognitive and emotional engagement, with

supplementary documentation of learning activities and teacher implementation logs to verify fidelity of the intervention.

The primary instruments included a standardized learning outcomes test aligned with the curriculum, a multidimensional student engagement scale measuring behavioral, emotional, and cognitive engagement, and an observation rubric to triangulate engagement indicators across data sources. Instrument quality was established through expert judgment for content validity, pilot testing, and reliability estimation using internal consistency coefficients, while inter-rater agreement was calculated for observation data to ensure scoring stability. Data analysis applied descriptive statistics and inferential testing, including ANCOVA to compare post-test outcomes while controlling for baseline differences, and regression-based modeling to examine the predictive contribution of engagement dimensions to learning outcomes within and across groups. Ethical safeguards were implemented through institutional approval, informed consent from students and guardians, voluntary participation, anonymity in reporting, and secure data handling procedures, ensuring that no participant experienced academic disadvantage as a result of group assignment or research participation.

RESULTS AND DISCUSSION

Baseline Equivalence and Post-Intervention Differences in Learning Outcomes

The empirical analysis began by establishing baseline comparability between the experimental and comparison groups to reduce threats to internal validity commonly associated with non-equivalent control group designs. Pre-test achievement scores indicated that both groups entered the intervention with broadly similar curricular readiness, although minor variance was observed across individual performance bands. This preliminary pattern justified the use of ANCOVA to statistically control for baseline differences and isolate the instructional effect attributable to structured collaborative learning. Such an approach aligns with methodological recommendations in quasi-experimental research, where random assignment is infeasible and statistical adjustment becomes essential for causal inference. The observed baseline stability provided a credible foundation for interpreting post-test gains as a function of the collaborative learning model rather than pre-existing academic disparities.

Post-test results demonstrated a consistent advantage for students exposed to structured collaborative learning, particularly in higher-order learning outcomes requiring application and conceptual integration. The experimental group exhibited a larger mean increase in achievement scores, suggesting that role-based interdependence and peer-regulation prompts supported deeper processing of instructional content. This finding resonates with prior evidence indicating that cooperative learning enhances academic goals and achievement when tasks are designed to foster meaningful interdependence rather than superficial group work (Mendo-Lázaro et al., 2022). In parallel, the comparison group showed improvement, yet the magnitude of change was smaller and more concentrated in lower-level recall items. The pattern supports the argument that teacher-directed instruction may sustain short-term knowledge accumulation while structured collaboration more effectively promotes transferable learning.

To quantify these differences with stronger inferential precision, ANCOVA was applied using pre-test scores as covariates and post-test scores as the dependent variable. The adjusted post-test mean for the experimental group remained higher than that of the comparison group after controlling for baseline achievement. This indicates that collaborative learning produced an independent contribution to learning outcomes beyond what could be explained by initial academic readiness. The result is consistent with studies emphasizing that cooperative learning effectiveness depends on implementation quality and the pedagogical competence of teachers in orchestrating group processes (Geletu, 2022). Consequently, the data suggest that the intervention's structure, rather than mere group formation, accounted for measurable academic benefits.

Beyond mean differences, the distributional pattern of gains revealed that structured collaboration particularly benefited students in the mid-achievement range. Students who initially demonstrated moderate proficiency showed the largest adjusted improvement, implying that collaborative scaffolding may be especially effective for learners who possess sufficient foundational knowledge but require support to consolidate and extend it. This aligns with research suggesting that collaborative learning supports cognitive enhancement by increasing active processing, elaboration, and meaningful engagement with tasks (Dada et al., 2023). In contrast, the lowest-achieving students improved but displayed smaller effect sizes, potentially due to limited prior knowledge constraining

their ability to contribute substantively to group reasoning. These results underscore the importance of careful role allocation and teacher facilitation to ensure equitable learning opportunities within collaborative structures.

The central quantitative trend is summarized in Table 1, which presents descriptive statistics for pre-test and post-test achievement scores in both groups. The table is positioned here to support interpretive continuity and to allow direct comparison of change trajectories. As shown in Table 1, the experimental group's post-test mean exceeded that of the comparison group, while the pre-test means remained closely aligned. This pattern provides descriptive support for the inferential conclusion that the collaborative model generated superior learning outcomes. The inclusion of standard deviations further indicates that score variability did not inflate disproportionately in the experimental group, suggesting that gains were not restricted to a small subset of high-performing students.

Table 1. Descriptive Statistics of Pre-Test and Post-Test Learning Outcomes by Group

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain
Experimental (Collaborative)	68.42 (8.11)	82.36 (7.54)	+13.94
Comparison (Teacher-Directed)	67.90 (8.29)	76.18 (8.06)	+8.28

Source: Primary data analysis from standardized achievement tests administered in the quasi-experimental study (Pre-test and Post-test)

The observed mean gain differential indicates that structured collaboration supported not only performance improvement but also a stronger consolidation of knowledge under comparable curricular exposure. This interpretation is consistent with cooperative learning literature in which role clarity, task interdependence, and accountability mechanisms produce robust achievement effects across domains (Suryadi et al., 2024). The empirical results also align with evidence from articulation-type cooperative learning models, which show measurable gains when students are required to verbalize understanding and negotiate meaning with peers (Indrawati & Desky, 2024). Importantly, these mechanisms are theoretically aligned with socio-constructivist principles, where learning is strengthened through dialogue, explanation, and shared problem solving. Therefore, the achievement outcomes can be interpreted as the product of structured interaction that increased cognitive elaboration rather than as an artifact of increased time-on-task alone.

The findings also support a broader conceptualization of collaborative learning as a student-centered pedagogical tool that reconfigures classroom epistemic authority. Under conventional instruction, students often occupy receptive roles, which may limit opportunities for self-regulation and conceptual negotiation. In contrast, structured collaboration distributes cognitive responsibility, enabling students to actively monitor understanding, justify reasoning, and resolve discrepancies in interpretations. Such processes reflect the functions of shared metacognitive regulation, which have been shown to predict deeper understanding in collaborative contexts (De Backer, Van Keer, & Valcke, 2022). The achievement gains in this study can therefore be interpreted as an outcome of increased metacognitive and dialogic activity embedded in the intervention design.

From an implementation perspective, the observed academic effects also depend on the fidelity of collaborative procedures and the degree to which teachers maintained the intended learning architecture. Teacher beliefs and classroom process quality are known to influence engagement and learning outcomes in technology-supported and structured environments (Wang et al., 2022). Even in non-digital collaborative contexts, the same logic applies, because instructional quality mediates whether collaboration becomes productive or degenerates into off-task socialization. The stability of achievement variance in the experimental group suggests that facilitation was sufficiently consistent to prevent excessive performance divergence. This supports the interpretation that the intervention was implemented with adequate procedural integrity, as corroborated by teacher logs and structured documentation.

The results further contribute to ongoing debates about whether collaborative learning reliably improves academic performance or whether its effects are contingent on context and learner characteristics. Evidence indicates that collaborative learning is not universally beneficial unless it is

paired with explicit regulation supports, task structure, and accountability mechanisms (Qureshi et al., 2023). The present findings reinforce this conditional perspective, as the intervention incorporated defined roles and peer-regulation prompts rather than relying on unstructured group work. In doing so, the study aligns with research on regulation profiles in computer-supported collaborative learning, which emphasizes that structured regulation is associated with stronger performance, motivation, and self-efficacy (De Backer et al., 2022). Consequently, the academic gains observed here are best interpreted as the effect of collaboration that was intentionally engineered to produce learning rather than collaboration as a generic classroom arrangement.

Multidimensional Student Engagement Under Structured Collaborative Learning

Student engagement was examined as a multidimensional construct encompassing behavioral, emotional, and cognitive components, consistent with contemporary conceptual definitions in educational psychology. Pre-intervention engagement scores indicated no substantial baseline divergence between the experimental and comparison groups, suggesting that subsequent differences could be interpreted as intervention-related rather than structurally pre-existing. This baseline pattern was essential because engagement is frequently shaped by classroom climate, teacher beliefs, and instructional routines that can vary across classes even within the same school context (Wang et al., 2022). The use of triangulated measures, combining structured observations and self-report scales, strengthened the interpretive credibility of engagement trends by reducing mono-method bias. Such triangulation aligns with engagement scholarship emphasizing that engagement is not a single observable behavior but a layered system of participation, affect, and cognition (Martin & Borup, 2022).

Behavioral engagement outcomes revealed a distinct shift in the experimental group, as evidenced by increased on-task collaboration, more frequent peer-to-peer academic talk, and a lower incidence of passive seatwork during observation windows. These indicators were consistently reflected across the observation rubric, suggesting that the intervention produced visible changes in classroom participation patterns rather than merely influencing students' private attitudes. The comparison group maintained stable behavioral engagement, but observational notes indicated that participation remained concentrated among a smaller subset of students who were already confident in responding to teacher prompts. This distributional pattern is theoretically important because collaborative learning is often argued to democratize participation by redistributing interactional opportunities across students rather than privileging high-achieving individuals (Okolie et al., 2022). Consequently, the behavioral engagement gains can be interpreted as a structural effect of role-defined interdependence that made participation a functional necessity rather than an optional performance.

Emotional engagement also improved more strongly in the experimental group, particularly in students' reported enjoyment, sense of belonging, and perceived value of learning activities. The improvement was not trivial because emotional engagement is frequently resistant to short-term instructional changes unless students experience consistent autonomy support and social relatedness. This aligns with evidence suggesting that collaborative environments promote positive affect when learners perceive mutual support and constructive interdependence rather than competitive evaluation (Qureshi et al., 2023). The comparison group displayed modest emotional engagement gains, yet students' open-ended reflections indicated that enjoyment remained closely tied to teacher charisma rather than to task structure. The observed emotional patterns indicate that structured collaboration may shift affective orientation from teacher-centered motivation to peer-mediated academic belonging.

Cognitive engagement demonstrated the most analytically significant differences, as the experimental group reported greater use of elaboration strategies, persistence during difficult tasks, and active monitoring of comprehension. These findings are consistent with research on shared metacognitive regulation, which emphasizes that collaborative learning becomes academically productive when students coordinate planning, monitoring, and evaluation during group work (De Backer, Van Keer, & Valcke, 2022). The intervention's peer-regulation prompts likely served as externalized scaffolds that supported students' internal regulation processes, particularly for learners who previously relied on teacher explanation. In contrast, the comparison group showed smaller increases in cognitive engagement, with several students indicating that they studied primarily to complete assignments rather than to refine conceptual understanding. The pattern suggests that collaborative learning promoted a shift from compliance-driven engagement toward mastery-oriented cognitive investment.

To synthesize these multidimensional outcomes, Table 2 presents descriptive statistics for engagement dimensions in both groups across pre-test and post-test measurement points. The table is placed here to enable direct interpretation of whether engagement gains were balanced across dimensions or concentrated in specific components. As indicated in Table 2, the experimental group demonstrated stronger post-intervention scores in behavioral, emotional, and cognitive engagement, with the largest mean gain observed in cognitive engagement. This distribution is theoretically coherent because structured collaboration is expected to intensify metacognitive and elaborative processing more strongly than it influences affective orientation alone. The comparative pattern supports the interpretation that engagement improvements were not superficial participation effects but reflected deeper cognitive involvement.

Table 2. Pre- and Post-Intervention Student Engagement Scores by Group (Scale 1–5)

Engagement Dimension	Experimental Pre (SD)	Experimental Post (SD)	Comparison Pre (SD)	Comparison Post (SD)
Behavioral Engagement	3.12 (0.46)	4.01 (0.41)	3.10 (0.48)	3.42 (0.45)
Emotional Engagement	3.08 (0.50)	3.86 (0.44)	3.05 (0.52)	3.33 (0.49)
Cognitive Engagement	2.97 (0.53)	4.05 (0.43)	2.95 (0.55)	3.28 (0.50)

Source: Primary data analysis from student engagement questionnaires and structured classroom observation triangulation in the quasi-experimental study

The magnitude of cognitive engagement improvement suggests that the intervention functioned as more than a social arrangement and instead operated as a cognitive tool that reorganized how students approached learning tasks. This interpretation aligns with the argument that student-centered learning tools enhance cognitive functioning when they require learners to externalize reasoning and interactively refine understanding (Dada et al., 2023). It also resonates with findings that regulation profiles in collaborative learning environments predict performance, motivation, and self-efficacy, particularly when regulation is distributed across group members (De Backer et al., 2022). The present study's structured roles likely contributed to a more stable regulation profile by ensuring that monitoring and explanation were not monopolized by one student. Therefore, engagement outcomes can be interpreted as emergent properties of regulation architecture embedded in the collaborative model.

The engagement results are also consistent with broader evidence that collaborative learning environments, including technology-mediated variants, enhance participation and perceived learning value when learners engage in knowledge sharing and mutual accountability. Studies in social media-based collaborative learning report that performance gains are partly mediated by engagement and moderated by academic self-efficacy, indicating that engagement is not merely an outcome but a mechanism linking collaboration to achievement (Liu et al., 2022). Although the present intervention was implemented in a conventional classroom rather than through social media, the same mechanism is theoretically plausible because peer interaction and knowledge exchange operate similarly across modalities. This suggests that engagement should be conceptualized as a mediating pathway through which structured collaboration produces learning gains rather than as a secondary byproduct. The implication is that interventions focusing only on group formation without engagement scaffolds may fail to produce consistent achievement benefits.

A critical implication of these findings concerns the role of instructional design in shaping engagement sustainability across time. Engagement scholarship emphasizes that engagement is dynamic and context-sensitive, influenced by task authenticity, perceived autonomy, and social support rather than by instructional labels alone (Martin & Borup, 2022). The structured collaborative model likely supported autonomy by distributing decision-making across students, while also maintaining accountability through defined roles and interdependence. This design logic parallels evidence from computer-supported collaborative learning contexts where structured interaction improves students' perceptions and learning performance when scaffolds guide inquiry and collaboration (Adhami & Taghizadeh, 2024). The results therefore suggest that engagement gains can be achieved in formal

school settings when collaboration is intentionally designed to balance autonomy, structure, and social relatedness.

The findings also intersect with contemporary discussions about emerging educational technologies and their potential to amplify engagement when integrated into collaborative learning ecosystems. Although the present study did not deploy AI tools, research indicates that AI-enhanced learning environments can increase engagement by supporting feedback, personalization, and interactive participation, yet they also introduce risks related to equity and over-reliance (Nguyen et al., 2024). This is relevant because structured collaboration may serve as a protective pedagogical framework that maintains human-centered learning while selectively integrating technology for scaffolding. Similarly, research on learner engagement with large language models suggests that engagement can increase when autonomy and competence needs are supported, but the quality of engagement depends on instructional framing (Wang & Wang, 2024). The present results imply that collaboration design, rather than technology alone, remains the primary driver of meaningful engagement. Consequently, future interventions may benefit from combining structured collaboration with carefully governed digital supports.

The engagement outcomes can be interpreted as evidence that collaborative learning operates through social-interactional processes that transform classroom participation norms. Research on technology acceptance in educational collaboration indicates that learners' willingness to participate in knowledge-sharing environments depends on perceived usefulness, ease of use, and social influence factors (Alismaiel et al., 2022). Even in non-digital contexts, analogous perceptions shape whether students invest effort in collaborative tasks or disengage due to uncertainty and low perceived value. In addition, studies examining collaborative interaction spaces in video-conferencing contexts show that social interaction quality predicts knowledge-sharing behaviors and community formation, which are key components of sustained engagement (Yilmaz, 2024). The present study suggests that structured collaboration can cultivate these social-interactional conditions in face-to-face classrooms by stabilizing roles, norms, and accountability. As a result, engagement gains can be understood as an instructional effect rooted in social regulation, task design, and learner agency rather than as a transient motivational fluctuation.

Predictive Pathways Linking Engagement Dimensions to Learning Outcomes and Implementation Fidelity

To examine mechanisms rather than only group differences, regression-based modeling was conducted to estimate the predictive contribution of behavioral, emotional, and cognitive engagement to post-test learning outcomes. This analytic step was essential because quasi-experimental comparisons can identify outcome differences but do not automatically clarify how those differences are produced. The model treated post-test achievement as the criterion variable while including pre-test achievement and engagement dimensions as predictors, allowing the analysis to isolate incremental explanatory power. The inclusion of engagement dimensions aligns with empirical claims that engagement functions as a proximal driver of learning performance in collaborative settings rather than a distal correlate (Qureshi et al., 2023). The model was estimated within and across groups to determine whether the engagement–achievement relationship was structurally similar or context-dependent.

Results indicated that cognitive engagement emerged as the strongest and most stable predictor of post-test achievement, exceeding the predictive influence of behavioral and emotional engagement. This finding suggests that visible participation alone did not guarantee academic gain unless it was accompanied by sustained strategic processing and metacognitive effort. The pattern is consistent with scholarship on shared metacognitive regulation, which emphasizes that collaborative learning improves understanding when learners coordinate planning, monitoring, and evaluation rather than merely dividing tasks (De Backer, Van Keer, & Valcke, 2022). In the experimental group, peer-regulation prompts likely increased the probability that cognitive engagement translated into productive learning behaviors such as explanation, justification, and error correction. Consequently, the regression results support a mechanism-based interpretation in which collaboration improved learning primarily by intensifying cognitive investment.

Behavioral engagement demonstrated a positive but comparatively smaller predictive contribution to achievement, indicating that participation was beneficial yet not sufficient as a stand-alone mechanism. This outcome is theoretically coherent because behavioral engagement is often a

necessary condition for learning but does not specify the quality of cognitive operations occurring during participation. Observational records suggested that students in the experimental group were more frequently engaged in academically oriented dialogue, which likely increased the instructional value of behavioral engagement compared to the comparison group. This interpretation is aligned with evidence that collaborative learning enhances engagement and outcomes when group interaction is structured toward practical skill acquisition and task-relevant coordination (Okolie et al., 2022). The findings imply that behavioral engagement becomes academically consequential when it is tightly coupled with cognitive regulation rather than when it functions as compliance.

Emotional engagement displayed the weakest direct predictive association with post-test achievement when cognitive engagement and pre-test achievement were controlled. This does not indicate that emotional engagement is irrelevant, but it suggests that its effect may be indirect, operating through sustained persistence, willingness to participate, and long-term motivation rather than immediate test performance. Contemporary engagement frameworks argue that emotional engagement contributes to learning through mechanisms such as belonging and task value, which may influence effort allocation across time rather than within a short intervention window (Martin & Borup, 2022). The quasi-experimental timeframe may therefore have been sufficient to capture cognitive shifts but less sensitive to longer-term affective pathways. This interpretation also aligns with research suggesting that engagement dimensions operate in interdependent ways, where emotional engagement supports the conditions under which cognitive engagement is sustained.

Table 3 summarizes the standardized regression coefficients for the engagement dimensions predicting post-test achievement while controlling for baseline achievement. The table is positioned here because it directly supports the mechanism-focused interpretation that engagement dimensions contribute differentially to learning outcomes. As shown in Table 3, cognitive engagement produced the largest standardized coefficient, while behavioral engagement contributed moderately and emotional engagement contributed minimally under statistical control. This coefficient pattern provides quantitative evidence that the intervention's effectiveness was linked to cognitive regulation processes rather than to affective positivity alone. The results strengthen the claim that structured collaborative learning functions as a cognitive architecture that reorganizes students' approach to learning tasks.

Table 3. Regression Model Predicting Post-Test Achievement from Engagement Dimensions (Standardized Coefficients)

Predictor	β	p-value	Interpretation
Pre-Test Achievement	0.48	<0.001	Strong baseline control
Behavioral Engagement	0.19	0.012	Moderate positive predictor
Emotional Engagement	0.07	0.214	Non-significant under control
Cognitive Engagement	0.34	<0.001	Strongest engagement predictor

Source: Primary data analysis from regression-based modeling using engagement questionnaire scores and standardized post-test achievement outcomes

The regression findings are consistent with research demonstrating that regulation profiles in collaborative learning environments are strongly associated with performance, motivation, and self-efficacy. Studies in computer-supported collaborative learning indicate that learners with stronger regulatory coordination outperform peers even when overall participation levels appear similar (De Backer et al., 2022). The present results suggest that the structured role system may have increased the likelihood of adaptive regulation profiles by assigning monitoring, explanation, and summarization responsibilities to different group members. This is particularly important because unstructured collaboration often produces uneven cognitive labor distribution, where one student performs most reasoning while others remain peripheral. The findings imply that the intervention's design mitigated this risk and supported more equitable cognitive contribution. Consequently, the predictive model provides empirical support for the instructional logic of defined roles and peer-regulation prompts.

A further implication concerns learner autonomy and motivational regulation, which are frequently cited as mediators in collaborative learning success. Evidence indicates that group metacognition and motivational regulation strategies predict learner autonomy in collaborative environments, suggesting that students become more self-directed when collaboration is structured to require shared planning and accountability (Uslu & Durak, 2022). The strong predictive role of cognitive engagement in the present study can be interpreted as an operational reflection of autonomy, because cognitive engagement involves strategic effort, persistence, and self-monitoring. The intervention likely strengthened autonomy indirectly by reducing dependence on teacher explanation and increasing reliance on peer reasoning. This interpretation aligns with student-centered learning perspectives emphasizing that cognitive enhancement emerges when learners actively construct knowledge rather than receive it passively (Dada et al., 2023). The results therefore support a theoretical pathway from structured collaboration to autonomy-related engagement and subsequently to achievement.

Implementation fidelity data further strengthened the validity of these inferences by documenting that collaborative learning procedures were delivered with acceptable consistency. Teacher implementation logs indicated that defined roles were maintained across sessions, peer-regulation prompts were used as planned, and task interdependence was preserved rather than replaced by parallel individual work. This is significant because cooperative learning effects are highly sensitive to teacher competence and pedagogical skill in facilitating group processes (Geletu, 2022). Without fidelity, collaboration can become socially active but cognitively unproductive, leading to engagement without achievement. The present fidelity evidence suggests that the observed engagement and learning gains were likely attributable to the intended instructional design rather than to uncontrolled teacher improvisation. Consequently, the study provides a credible empirical basis for linking collaborative learning structure to measurable outcomes.

The mechanism-based interpretation is also supported by related research in collaborative environments beyond conventional classrooms, where structured interaction predicts both engagement and learning performance. Studies on social media-based collaborative learning indicate that knowledge sharing behaviors and perceived usefulness influence performance outcomes, and these relationships are moderated by academic self-efficacy (Liu et al., 2022; Sabah, 2023). Although the present intervention was not mediated by social media, the same logic applies because collaborative learning requires students to exchange information, evaluate contributions, and sustain mutual accountability. Technology acceptance research similarly indicates that perceived usefulness and ease of use shape willingness to participate in educational collaboration, implying that engagement is partially conditioned by students' beliefs about the value of collaborative processes (Alismaiel et al., 2022). These parallels suggest that structured collaboration may be interpreted as an analog to well-designed digital collaboration spaces, where interaction norms and usability shape engagement quality. The findings therefore contribute to a broader theoretical continuity between face-to-face and technology-mediated collaboration.

Contemporary work on collaborative activity recommendation systems and adaptive learning design also provides a useful interpretive lens for understanding why structured collaboration can produce stronger engagement–achievement coupling. Research on collaborative activity recommendations using artificial neural networks highlights that learners exhibit different collaborative styles, and matching tasks to these styles can improve collaborative effectiveness (Troussas et al., 2023). The present study did not algorithmically personalize collaboration, yet role-defined interdependence may have functioned as a low-tech equivalent by distributing responsibilities in ways that accommodated diverse participation preferences. Similarly, studies of smart classroom learning environments show that classroom process quality predicts engagement, indicating that structural features of instruction can shape how engagement translates into learning (Wang et al., 2022). These findings support the argument that collaborative learning is most effective when its structure anticipates variability in learner interaction styles. The results imply that future implementations could further strengthen outcomes by integrating adaptive role assignment or data-informed group formation.

The findings have forward-looking relevance for educational contexts increasingly shaped by digital collaboration tools and AI-mediated learning supports. Research suggests that AI can enhance engagement by supporting feedback and personalization, yet it also introduces challenges related to over-reliance, equity, and the need for pedagogical governance (Nguyen et al., 2024). Evidence from

video-conferencing collaboration indicates that technology acceptance, social interaction space, and knowledge-sharing behaviors are tightly interlinked, shaping whether collaboration becomes meaningful or superficial (Yilmaz, 2024). In addition, engagement research on large language models indicates that autonomy support and instructional framing influence whether learners engage cognitively or rely on AI outputs without deep processing (Wang & Wang, 2024). The present study suggests that structured collaborative learning provides a robust pedagogical foundation that can preserve cognitive engagement even as classrooms adopt new technologies. Consequently, the mechanism-focused results support a practical implication: collaboration should be designed as a regulated learning system that safeguards cognitive engagement, rather than as an unstructured social activity.

CONCLUSION

This quasi-experimental study provides empirical evidence that structured collaborative learning produces statistically and educationally meaningful improvements in students' learning outcomes and multidimensional engagement when compared with conventional teacher-directed instruction. After controlling for baseline achievement through ANCOVA, the experimental group demonstrated higher adjusted post-test performance, indicating that the intervention contributed independently to achievement gains. Engagement results triangulated from observations and self-report measures showed consistent increases in behavioral, emotional, and especially cognitive engagement, suggesting that collaborative structures enhanced both participation and deeper learning investment. Regression-based modeling further clarified that cognitive engagement was the strongest predictor of post-test achievement, while behavioral engagement contributed moderately and emotional engagement showed a weaker direct effect under statistical control. These findings support theoretical perspectives emphasizing shared metacognitive regulation, learner autonomy, and task interdependence as mechanisms through which collaboration improves learning. The study concludes that collaborative learning effectiveness depends on deliberate instructional design, implementation fidelity, and regulatory scaffolds that transform peer interaction into sustained cognitive work.

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