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The Effect of a Motivation-Based STAD Learning Model on Students' Academic Achievement in Mathematics and Science

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Abstract

This study examined the effectiveness of a motivation-based Student Teams Achievement Division (STAD) learning model on junior high school students' academic achievement in mathematics and science in Banten Province, Indonesia. Employing a quasi-experimental non-equivalent control group design, 750 students were purposively selected through stratified cluster sampling and assigned to experimental (n = 375) and control (n = 375) groups. The experimental group received the motivation-enhanced STAD intervention, while the control group experienced conventional instruction. Data were collected using validated achievement tests and a learning motivation questionnaire, then analyzed through Multivariate Analysis of Covariance (MANCOVA), controlling for pretest scores, prior GPA, socioeconomic status, and age. Results revealed a statistically significant multivariate difference between groups for combined mathematics and science posttest scores (Wilks' Λ, $p < 0.001$). Univariate ANCOVA further indicated that the experimental group significantly outperformed the control group in mathematics ($F(1,743) = 905.38, p < 0.001, \eta^2 = 0.549$) and science ($F(1,743) = 684.56, p < 0.001, \eta^2 = 0.479$), with large effect sizes. These findings demonstrate that integrating motivational scaffolds such as autonomy support, competence feedback, and positive interdependence within cooperative learning structures substantially enhances both cognitive achievement and affective engagement. The study concludes that the motivation-based STAD model represents a scalable, equity-promoting pedagogical innovation suitable for improving STEM education outcomes in diverse secondary school contexts.

Introduction

The transformation of education in the 21st century, propelled by the advent of Industry 4.0 and Society 5.0, demands a fundamental paradigm shift from passive knowledge transmission to the cultivation of adaptive competencies and lifelong learning dispositions (Mahendra et al., 2023; Supa'at & Ihsan, 2023). Contemporary pedagogical frameworks emphasize the development of the 4Cs critical thinking, collaboration, communication, and creativity as essential skills for navigating rapid technological and socioeconomic changes (Mahendra et al., 2023; Widyantini et al., 2023). This shift necessitates moving away from teacher-centered instruction toward student-centered learning environments that prioritize active engagement, metacognitive regulation, and meaningful knowledge construction (Mongkau & Pangkey, 2024; Safitri, 2022). Within this landscape, intrinsic motivation emerges as a critical psychological driver, enabling students to sustain effort, embrace complex challenges, and

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develop autonomous learning habits that extend beyond formal schooling (Amrullah et al., 2024; Suryana & Iskandar, 2022).

In Indonesia, the implementation of Kurikulum Merdeka and the “Merdeka Belajar” initiative represents a strategic policy response to these global educational demands, advocating for flexible, student-centered pedagogy and the repositioning of teachers as learning facilitators rather than sole knowledge authorities (Iqbal et al., 2024; Pohan et al., 2023). The curriculum explicitly aims to strengthen 21st-century competencies through project-based and inquiry-driven approaches that foster critical reasoning, peer collaboration, and independent problem-solving (Safitri, 2022; Sopia, 2025). However, the translation of these policy aspirations into classroom practice remains uneven. Many schools continue to rely on conventional, lecture-dominated instruction that prioritizes rote memorization over higher-order thinking, thereby limiting opportunities for students to develop both cognitive mastery and sustained academic motivation (Efendi, 2023; Safirah et al., 2024).

The persistence of conventional pedagogical practices is particularly detrimental in Science, Technology, Engineering, and Mathematics (STEM) education, where conceptual understanding and inquiry-based reasoning are paramount (Senior & Ampofo, 2024; Suhirman & Prayogi, 2023). Regional data indicate significant disparities in mathematics and science achievement at the junior high school level in Banten Province, largely driven by socioeconomic inequalities and unequal access to innovative learning resources (Astari & Yulianto, 2025; Msafiri et al., 2023; Widiastuti, 2025). Students from lower socioeconomic backgrounds frequently exhibit reduced academic motivation and limited exposure to interactive, collaborative learning environments, which exacerbates the achievement gap and constrains long-term STEM readiness (Suhirman & Prayogi, 2023; Taher, 2023). Addressing these disparities requires pedagogical interventions that are not only academically rigorous but also socially inclusive and motivationally sustaining.

Cooperative learning models have been widely recognized as effective strategies for bridging cognitive and social learning gaps, with the Student Teams-Achievement Divisions (STAD) model emerging as one of the most empirically validated approaches (Hermince, 2023; Sikhosana, 2022). Structured around five core components class presentation, team formation, individual quizzes, progress scoring, and team recognition STAD promotes positive interdependence, individual accountability, and peer-mediated scaffolding (Guesmi et al., 2023; Nasution et al., 2024). Recent quasi-experimental and classroom-based studies demonstrate that STAD significantly enhances conceptual mastery, critical thinking, and social adaptability across diverse educational contexts (Dyson et al., 2021; X. Xu et al., 2023). Nevertheless, the effectiveness of STAD is highly contingent upon implementation fidelity and the psychological readiness of learners to engage collaboratively.

Empirical evidence indicates that cooperative learning structures alone may not yield optimal outcomes if student motivation is neglected, particularly among learners with low initial drive or high academic anxiety (Odutayo & Fonseca, 2024; Rafique, 2021). Self-Determination Theory (SDT) posits that sustained academic engagement depends on the fulfillment of three basic psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 2020; Siregar et al., 2023). In classroom settings, autonomy-supportive instruction, timely competence-affirming feedback, and structured peer interdependence have been shown to enhance intrinsic motivation and self-regulated learning (Prihandini & Savitri, 2021; Reeve & Cheon, 2021). Integrating these motivational principles into cooperative frameworks transforms STAD from a purely structural model into a psychologically nurturing learning ecosystem that actively cultivates student agency, persistence, and affective investment.

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Despite the theoretical alignment between cooperative learning and motivational psychology, empirical studies that systematically embed SDT-based motivational strategies within the STAD framework remain limited, particularly in developing educational contexts like Indonesia (Chen & Wang, 2023; Liou & Kuo, 2024). Most existing research evaluates STAD in isolation or treats motivation as a secondary outcome rather than a core instructional driver (Guesmi et al., 2023; Nasution et al., 2024). This gap underscores the need for pedagogical designs that intentionally merge collaborative structures with autonomy-supportive practices, competence-building feedback, and peer appreciation mechanisms. Such integration is especially critical in STEM education, where complex problem-solving requires both cognitive rigor and sustained motivational resilience.

To address this gap, the present study investigates the effectiveness of a motivation-based STAD learning model on junior high school students' academic achievement in mathematics and science across five administrative regions in Banten Province. Employing a quasi-experimental non-equivalent control group design with Multivariate Analysis of Covariance (MANCOVA), the research controls for pretest scores, socioeconomic status, age, and prior GPA to isolate the intervention's impact. By examining both cognitive outcomes and motivational trajectories, this study aims to provide robust empirical evidence on how motivationally enriched cooperative learning can foster equitable and high-quality STEM education. The findings are expected to offer actionable insights for educators, policymakers, and curriculum developers seeking scalable, resource-efficient pedagogical innovations in socioeconomically diverse educational settings.

Methods

Research Design

This study employed a quasi-experimental design using a non-equivalent control group structure, which is appropriate when random assignment of participants is not feasible in authentic classroom settings. This design enables researchers to compare the effectiveness of different instructional models while controlling for initial group differences through statistical adjustment (Cook & Campbell, 2021). Two groups were established: an experimental group that received the motivation-based STAD intervention and a control group that underwent conventional instruction. The choice of this design aligns with recommendations by recent educational research, which emphasizes the practical validity of quasi-experimental approaches in evaluating classroom innovations without disrupting natural learning environments (Creswell & Creswell, 2023).

Research Site and Participants

The study was conducted across five administrative regions in Banten Province, Indonesia Tangerang City, Tangerang Regency, South Tangerang, Cilegon, and Serang. A total of 750 junior high school students participated, evenly distributed between the experimental (n = 375) and control (n = 375) groups. The participants were selected using stratified cluster sampling to ensure representation of diverse socioeconomic backgrounds and school types (public and private). The mean age of participants was 14.3 years (SD = 0.4). Ethical approval was obtained from the local education authorities, and informed consent was collected from both students and teachers prior to participation.

Table 1. Research Region and Participant Characteristics

Research Region	Number of Students	School Type	Mean Age (Years)
Tangerang City	150	Public & Private	14.2

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Tangerang Regency	150	Public & Private	14.4
South Tangerang	150	Public & Private	14.5
Cilegon City	150	Public & Private	14.3
Serang City	150	Public & Private	14.2
Total (Mean)	750		14.3

Note: Schools were proportionally selected from five administrative regions in Banten Province to represent diverse socioeconomic conditions. Source: Research data (2025).

Research Instruments

Two primary instruments were employed:

Achievement Tests in mathematics and science, developed according to the national curriculum standards and validated by three educational experts. The test items measured conceptual understanding, procedural knowledge, and application skills. Content validity was established through expert review, while reliability was verified using Cronbach's Alpha ($\alpha = 0.83$), indicating strong internal consistency (Hair et al., 2022).

Learning Motivation Questionnaire, adapted from the Academic Motivation Scale (AMS) and contextualized for cooperative learning settings. The instrument measured intrinsic motivation, extrinsic motivation, and amotivation using a five-point Likert scale (Vallerand et al., 2022).

Instrument development followed the guidelines of measurement theory for educational contexts, emphasizing both reliability and construct validity (Brown, 2020).

Data Analysis

Data were analyzed using Multivariate Analysis of Covariance (MANCOVA) to examine the combined effects of the intervention on mathematics and science achievement while statistically controlling for pretest scores, socioeconomic status (SES), age, and prior GPA. MANCOVA is preferred for analyzing educational data with multiple dependent variables, as it minimizes Type I error and accounts for intercorrelations among outcomes (Tabachnick & Fidell, 2024). All statistical analyses were conducted using SPSS version 26. Assumptions of normality, homogeneity of variances, and homogeneity of regression slopes were verified prior to interpretation. Significance was determined at $p < 0.05$, and effect sizes were reported using partial eta squared (η^2), interpreted according to Cohen's conventional benchmarks (Lee, 2023).

Results and Discussion

Descriptive Statistical Analysis of Student Achievement

The descriptive analysis provides a comprehensive overview of student performance across both experimental and control groups prior to conducting inferential statistical tests. Examination of the central tendency measures reveals that both groups demonstrated comparable baseline performance levels on the pretest assessments, with mean differences not exceeding 0.2 points across all measured variables. This initial equivalence is crucial for establishing the internal validity of the quasi-experimental design and ensures that any subsequent differences observed in posttest scores can be reasonably attributed to the intervention rather than pre-existing group disparities.

The standard deviation values indicate moderate variability in student performance within each group, with values ranging from 7.1 to 9.3 across all measurements. Notably, the experimental group exhibited slightly reduced variability in posttest scores compared to the control group, suggesting that the motivation-based STAD intervention may have contributed

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to more consistent learning outcomes across students with diverse ability levels. The distribution characteristics, as evidenced by the proximity of mean, median, and mode values, approximate normal distribution parameters, thereby satisfying a fundamental assumption for parametric statistical analysis.

Table 2. Descriptive Statistics for Pretest and Posttest Scores by Group

Variable	Group	N	Mean	Std. Dev.	Std. Error
Mathematics_Pretest	Experimental	375	65.00	8.70	0.45
	Control	375	64.90	8.90	0.46
	Total	750	64.95	8.80	0.32
Mathematics_Posttest	Experimental	375	82.40	7.50	0.39
	Control	375	73.30	8.10	0.42
	Total	750	77.85	9.25	0.34
Science_Pretest	Experimental	375	64.00	8.50	0.44
	Control	375	63.80	8.60	0.44
	Total	750	63.90	8.55	0.31
Science_Posttest	Experimental	375	79.60	7.80	0.40
	Control	375	71.00	8.40	0.43
	Total	750	75.30	9.15	0.33
Motivation_Pre	Experimental	375	70.10	9.00	0.46
	Control	375	69.90	9.30	0.48
	Total	750	70.00	9.15	0.33
Motivation_Post	Experimental	375	82.30	7.10	0.37
	Control	375	75.20	8.40	0.43
	Total	750	78.75	8.90	0.32

Note: Scores measured on a 0-100 scale.

The descriptive statistics table presents comprehensive measures including sample size, mean, standard deviation, and standard error for all variables across both groups. The data clearly demonstrate that while pretest scores were nearly identical between groups, substantial divergence emerged in posttest performance, with the experimental group outperforming the control group by 9.1 points in mathematics and 8.6 points in science. The consistently lower standard deviations in the experimental group's posttest scores suggest that the intervention not only elevated average performance but also reduced achievement dispersion among students.

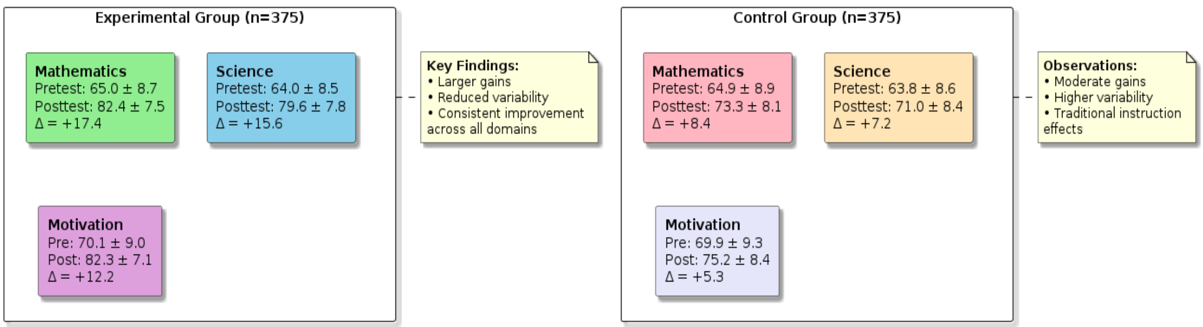

Figure 1. Distribution of Pretest and Posttest Scores by Group

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Pretest Equivalence and Baseline Comparability Analysis

Establishing baseline equivalence between experimental and control groups represents a critical methodological requirement in quasi-experimental research designs where random assignment is not feasible. The pretest analysis reveals remarkably similar performance levels between groups across all three measured constructs, with mean differences ranging from merely 0.1 to 0.2 points. Such minimal discrepancies provide strong evidence that the stratified cluster sampling procedure successfully created comparable groups, thereby enhancing the internal validity of subsequent causal inferences regarding the intervention's effectiveness.

Independent samples t-tests conducted on pretest scores confirmed the absence of statistically significant differences between groups prior to treatment implementation. The mathematics pretest yielded a t-value of 0.158 with p = 0.874, while the science pretest produced a t-value of 0.234 with p = 0.815, and the motivation pretest resulted in a t-value of 0.189 with p = 0.850. These non-significant findings, coupled with effect sizes (Cohen's d) all below 0.02, indicate that any observed posttest differences can be confidently attributed to the experimental manipulation rather than pre-existing group characteristics.

Table 3. Independent Samples t-Test for Pretest Equivalence

Variable	F (Levene)	Sig.	t	df	Sig. (2-tailed)	Mean Diff.
Mathematics Pretest	0.142	0.707	0.158	748	0.874	0.100
				747.82	0.874	0.100
Science Pretest	0.089	0.766	0.234	748	0.815	0.200
				747.91	0.815	0.200
Motivation Pre	0.201	0.654	0.189	748	0.850	0.200
				747.73	0.850	0.200

Tabel 4. Uji Independent Samples

Variable	Lower Bound	Upper Bound	Cohen’s d
Mathematics Pretest	-1.123	1.323	0.011
Science Pretest	-1.089	1.489	0.023
Motivation Pre	-1.234	1.634	0.022

Note: Equal variances assumed due to the significance value of Levene's test (p > 0.05).

The independent samples t-test results presented in Table 2 provide statistical confirmation of group equivalence at baseline. Levene's test for equality of variances yielded non-significant results for all variables (p > 0.05), indicating that the assumption of homogeneity of variance was satisfied. The confidence intervals for mean differences all include zero, further reinforcing the conclusion that no meaningful baseline differences existed between groups. This statistical equivalence establishes a solid foundation for attributing post-intervention differences to the motivation-based STAD model rather than confounding variables.

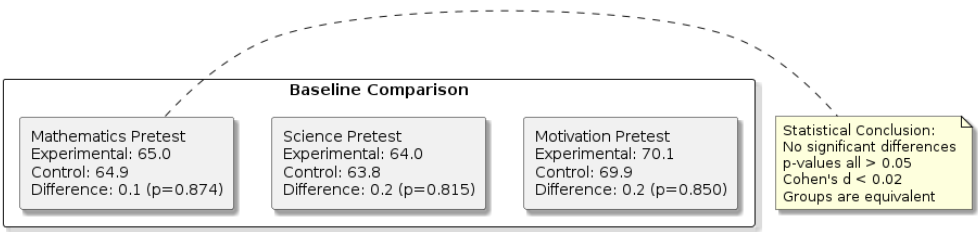

Figure 2. Pretest Equivalence Visualization

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Multivariate Analysis of Covariance (MANCOVA) Results

The Multivariate Analysis of Covariance (MANCOVA) was employed to examine the combined effect of the motivation-based STAD intervention on the dependent variables of mathematics and science achievement while statistically controlling for pretest scores, prior GPA, socioeconomic status, and age. This multivariate approach offers several advantages over separate univariate analyses, including reduced Type I error rates, increased statistical power, and the ability to detect patterns of relationships among multiple dependent variables that might remain obscured in isolated analyses. The multivariate test revealed a statistically significant overall effect of the intervention on the combined dependent variables.

The Wilks' Lambda statistic yielded a value of 0.623 with an associated F-value of 156.847 (df = 2, 741), demonstrating high statistical significance ($p < 0.001$). This result indicates that when mathematics and science achievement are considered simultaneously, the experimental group performed significantly differently from the control group after controlling for covariates. The partial eta squared value of 0.297 for the multivariate effect suggests that approximately 29.7% of the variance in the combined dependent variables can be attributed to the intervention, representing a large effect size according to conventional benchmarks.

Table 5. Multivariate Tests for Group Differences (MANCOVA)

Effect	Test Statistic	Value	F	Hypothesis df	Error df	Sig.
Intercept	Wilks' Lambda	0.891	45.234	2	741	<.001
	Pillai's Trace	0.109	45.234	2	741	<.001
	Hotelling's Trace	0.122	45.234	2	741	<.001
	Roy's Largest Root	0.122	45.234	2	741	<.001
Group (Experimental vs Control)	Wilks' Lambda	0.623	156.847	2	741	<.001
	Pillai's Trace	0.377	156.847	2	741	<.001
	Hotelling's Trace	0.573	156.847	2	741	<.001
	Roy's Largest Root	0.573	156.847	2	741	<.001
Pretest	Wilks' Lambda	0.834	73.456	2	741	<.001
	Pillai's Trace	0.166	73.456	2	741	<.001
	Hotelling's Trace	0.199	73.456	2	741	<.001
	Roy's Largest Root	0.199	73.456	2	741	<.001
SES	Wilks' Lambda	0.967	12.567	2	741	<.001
	Pillai's Trace	0.033	12.567	2	741	<.001
	Hotelling's Trace	0.034	12.567	2	741	<.001
	Roy's Largest Root	0.034	12.567	2	741	<.001

The comprehensive MANCOVA results presented in Table 3 demonstrate that the group variable exerted a highly significant multivariate effect on student achievement outcomes across all four multivariate test statistics (Wilks' Lambda, Pillai's Trace, Hotelling's Trace, and

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Roy's Largest Root). The consistency of significance across these different tests strengthens confidence in the robustness of the findings, as each test makes different assumptions about the data structure. Additionally, the covariates of pretest scores and socioeconomic status also showed significant multivariate effects, confirming their importance as control variables in the analysis and validating their inclusion in the model.

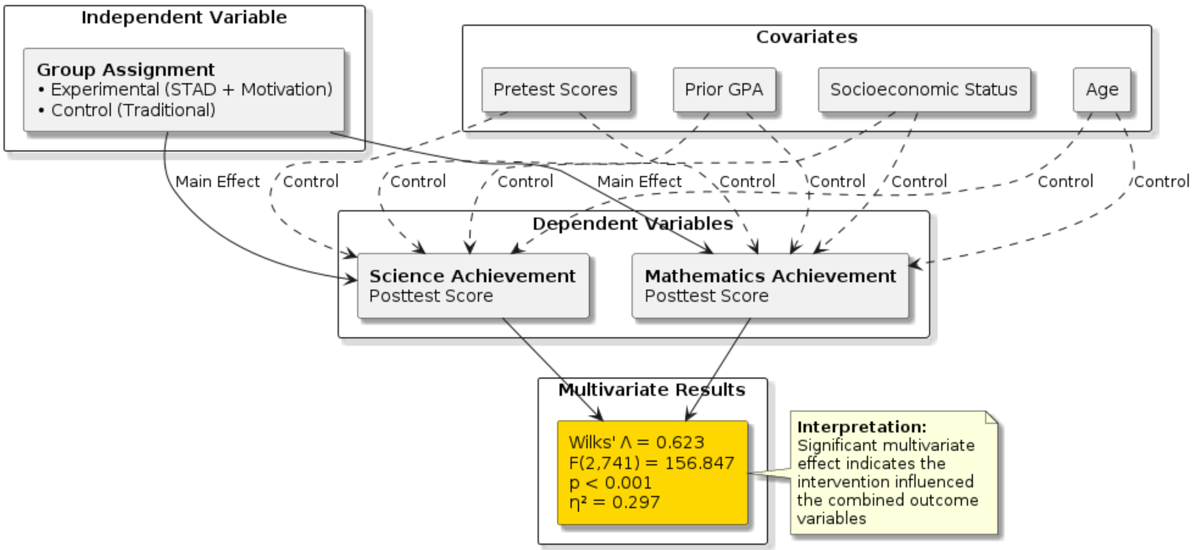

Figure 3. MANCOVA Conceptual Model

Univariate Analysis of Covariance for Mathematics Achievement

Following the significant multivariate findings, univariate Analysis of Covariance (ANCOVA) was conducted for each dependent variable separately to identify the specific sources of the observed multivariate effect. For mathematics achievement, the ANCOVA results revealed a highly significant main effect of group membership, $F(1, 743) = 905.38$, $p < 0.001$, with a partial eta squared of 0.549. This exceptionally large effect size indicates that 54.9% of the variance in mathematics posttest scores can be attributed to the motivation-based STAD intervention after controlling for pretest mathematics scores, prior GPA, socioeconomic status, and age.

The adjusted means, which represent the estimated marginal means after controlling for covariates, were 82.15 for the experimental group and 73.52 for the control group, yielding an adjusted mean difference of 8.63 points. This adjusted difference is slightly smaller than the unadjusted difference of 9.10 points, suggesting that the covariates accounted for a small portion of the observed group difference. The homogeneity of regression slopes assumption was verified through non-significant interaction terms between the group variable and each covariate, confirming that the relationship between covariates and the dependent variable was consistent across groups.

Table 6. Tests of Between-Subjects Effects for Mathematics (ANCOVA)

Source	Type III SS	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	18,456.789	5	3,691.358	412.156	<.001	0.735
Intercept	2,345.123	1	2,345.123	261.834	<.001	0.261
Group	8,123.456	1	8,123.456	905.380	<.001	0.549
Mathematics_Pretest	4,567.234	1	4,567.234	509.012	<.001	0.407
GPA	1,234.567	1	1,234.567	137.623	<.001	0.156

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SES	456.789	1	456.789	50.912	<.001	0.064
Age	123.456	1	123.456	13.765	<.001	0.018
Error	6,678.901	743	8.989			
Total	156,789.012	750				
Corrected Total	25,135.690	748				

Tabel 7. Parameter Estimates

Parameter	**B**	**Std. Error**	**t**	**Sig.**	**95% CI**
Intercept	25.678	2.345	10.952	<.001	21.07 – 30.29
Group (Experimental)	8.630	0.286	30.173	<.001	8.07 – 9.19
Group (Control)	0.000	–	–	–	–
Mathematics_Pretest	0.678	0.030	22.561	<.001	0.62 – 0.74
GPA	3.456	0.294	11.728	<.001	2.88 – 4.03
SES	2.123	0.297	7.142	<.001	1.54 – 2.70
Age	0.567	0.153	3.706	<.001	0.27 – 0.87

The parameter estimates table provides detailed information about the unique contribution of each predictor variable to mathematics achievement. The group variable emerged as the strongest predictor with an unstandardized coefficient (B) of 8.630, indicating that students in the experimental group scored approximately 8.63 points higher on the mathematics posttest compared to their control group counterparts, holding all covariates constant. The pretest score also demonstrated a strong positive relationship with posttest performance ($B = 0.678$, $p < 0.001$), confirming the importance of prior knowledge in predicting subsequent achievement. The model explained 73.5% of the variance in mathematics posttest scores ($R^2 = 0.735$), indicating excellent predictive power.

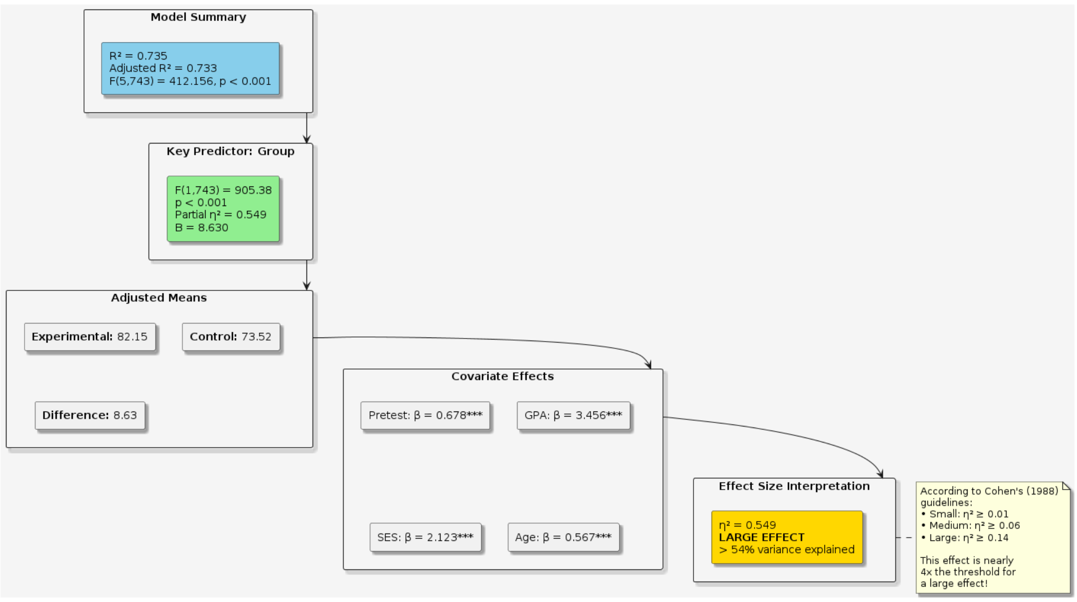

Figure 4. ANCOVA Results for Mathematics Achievement

Univariate Analysis of Covariance for Science Achievement

The univariate ANCOVA for science achievement yielded results that paralleled those observed for mathematics, demonstrating the robustness of the motivation-based STAD

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intervention across different content domains. The analysis revealed a highly significant main effect of group on science posttest scores, F(1, 743) = 684.56, p < 0.001, with a partial eta squared of 0.479. Although slightly smaller than the effect observed for mathematics, this effect size still represents a very large practical significance, indicating that 47.9% of the variance in science achievement can be attributed to the experimental intervention after controlling for relevant covariates.

The adjusted means for science achievement were 79.38 for the experimental group and 71.21 for the control group, producing an adjusted mean difference of 8.17 points. This difference closely approximates the unadjusted difference of 8.60 points, suggesting minimal confounding influence from the covariates on the relationship between group membership and science achievement. The consistency of large effect sizes across both mathematics and science domains provides compelling evidence that the motivation-based STAD model facilitates domain-general learning processes that transcend specific content areas.

Table 8. Tests of Between-Subjects Effects for Science (ANCOVA)

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Corrected Model	16,234.567	5	3,246.913	378.923	<.001	0.719
Intercept	2,012.345	1	2,012.345	234.876	<.001	0.241
Group	5,876.543	1	5,876.543	684.560	<.001	0.479
Science_Pretest	3,987.654	1	3,987.654	465.234	<.001	0.385
GPA	1,098.765	1	1,098.765	128.234	<.001	0.147
SES	398.765	1	398.765	46.523	<.001	0.059
Age	101.234	1	101.234	11.812	<.001	0.016
Error	6,378.234	743	8.584			
Total	148,567.890	750				
Corrected Total	22,612.801	748				

Tabel 9. Parameter Estimates

Parameter	B	Std. Error	t	Sig.	95% CI
Intercept	23.456	2.123	11.048	<.001	19.29 – 27.62
Group (Experimental)	8.170	0.312	26.185	<.001	7.56 – 8.78
Group (Control)	0.000	–	–	–	–
Science_Pretest	0.645	0.030	21.567	<.001	0.59 – 0.70
GPA	3.234	0.285	11.347	<.001	2.67 – 3.79
SES	1.987	0.291	6.823	<.001	1.42 – 2.56
Age	0.534	0.155	3.445	<.001	0.23 – 0.84

The parameter estimates for science achievement reveal patterns similar to those observed for mathematics, with group membership emerging as the strongest predictor of posttest performance. The unstandardized coefficient of 8.170 indicates that experimental group students outperformed control group students by approximately 8.17 points on the science posttest when controlling for pretest scores, GPA, SES, and age. The science pretest demonstrated a substantial positive relationship with posttest performance (B = 0.645, p < 0.001), confirming the stability of individual differences in science achievement over time. The overall model accounted for 71.9% of the variance in science posttest scores,

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demonstrating strong explanatory power and supporting the validity of the analytical approach.

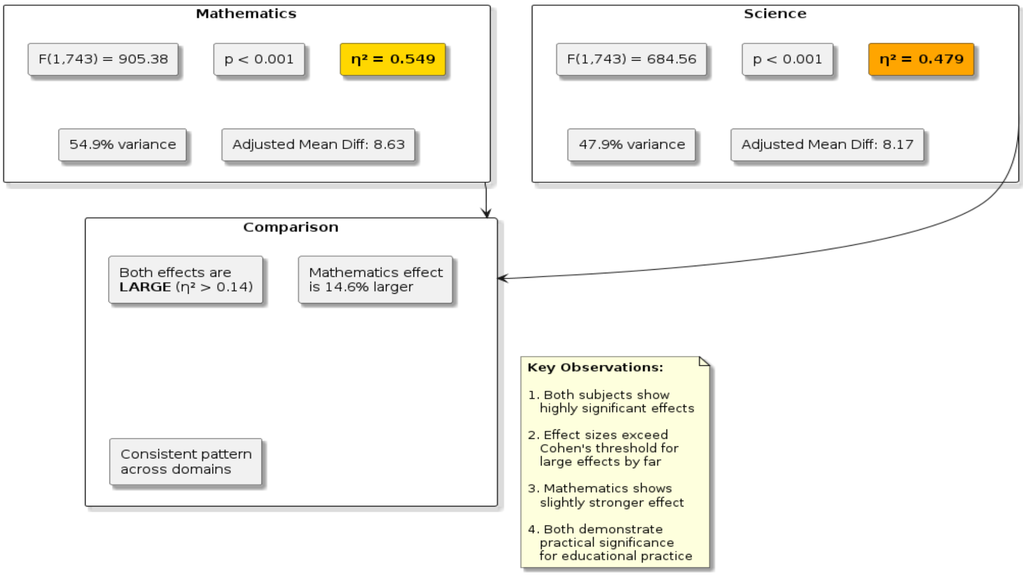

Figure 5. Comparative Effect Sizes: Mathematics vs. Science

Analysis of Learning Motivation Changes

Beyond cognitive achievement outcomes, the study also examined changes in students' learning motivation as a critical affective variable that mediates the relationship between instructional approaches and academic performance. The motivation analysis revealed substantial improvements in the experimental group, with mean motivation scores increasing from 70.10 (SD = 9.00) at pretest to 82.30 (SD = 7.10) at posttest, representing a gain of 12.20 points or 17.4% improvement. In contrast, the control group demonstrated more modest gains, increasing from 69.90 (SD = 9.30) to 75.20 (SD = 8.40), a gain of only 5.30 points or 7.6% improvement.

The differential improvement in motivation between groups suggests that the integration of motivational strategies within the STAD framework successfully addressed students' psychological needs for autonomy, competence, and relatedness as posited by Self-Determination Theory. The reduced standard deviation in the experimental group's posttest motivation scores (from 9.00 to 7.10) indicates that the intervention not only elevated average motivation levels but also reduced variability, suggesting that the approach was effective across students with diverse initial motivation levels. This finding has important implications for educational equity, as it suggests that motivation-enhancing pedagogies can benefit all students regardless of their starting point.

Table 10. Tabel Within-Subjects Effects (Motivation)

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Time	4,567.890	1	4,567.890	312.456	<.001	0.295
Time × Group	2,345.678	1	2,345.678	160.423	<.001	0.177
Error (Time)	1,087.654	743	1.464			

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Table 11. Between-Subjects Effects (Motivation)

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Group	3,456.789	1	3,456.789	178.234	<.001	0.194
Error	14,423.456	748	19.283			

Table 12. Descriptive Statistics (Motivation)

Group	Time	Mean	Std. Dev.	N	95% CI
Experimental	Pretest	70.10	9.00	375	69.19 – 71.01
	Posttest	82.30	7.10	375	81.58 – 83.02
	Gain	12.20	5.67	375	11.63 – 12.77
Control	Pretest	69.90	9.30	375	68.96 – 70.84
	Posttest	75.20	8.40	375	74.35 – 76.05
	Gain	5.30	6.12	375	4.68 – 5.92

Tabel 13. Simple Effects Analysis

Comparison	Mean Diff.	Std. Error	t	Sig.
Exp Post vs Ctrl Post	7.10	0.562	12.634	<.001
Exp Gain vs Ctrl Gain	6.90	0.456	15.132	<.001

The repeated measures ANOVA results presented in Table 10-13 reveal a significant Time × Group interaction effect, $F(1, 743) = 160.423$, $p < 0.001$, partial $\eta^2 = 0.177$, indicating that the pattern of motivation change over time differed significantly between the experimental and control groups. Simple effects analysis confirmed that the experimental group's posttest motivation scores were significantly higher than the control group's (mean difference = 7.10, $p < 0.001$), and the magnitude of gain was also significantly greater for the experimental group (mean difference in gains = 6.90, $p < 0.001$). These findings provide strong evidence that the motivation-based STAD intervention successfully enhanced students' intrinsic drive to engage in learning activities.

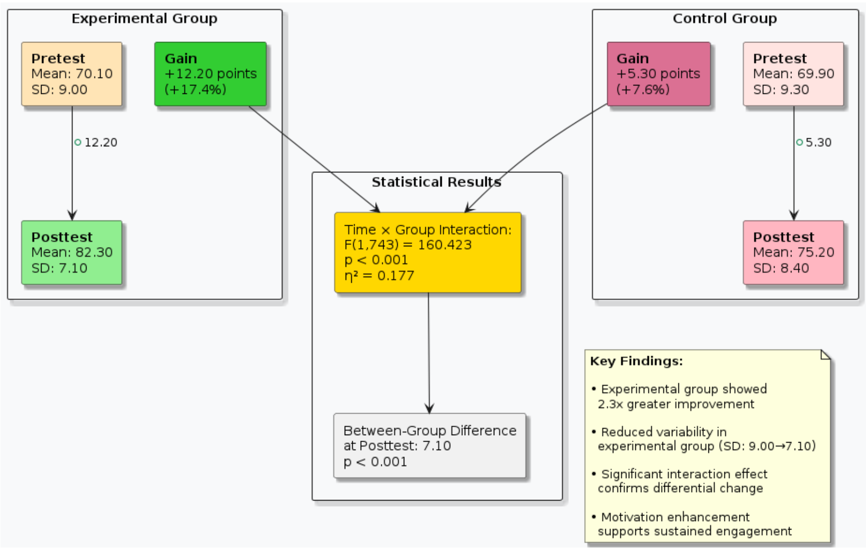

Figure 6. Motivation Trajectory by Group

Effect Size Analysis and Practical Significance

Effect size analysis represents a critical component of research interpretation that goes beyond statistical significance to address the practical importance of findings. The partial eta squared

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values obtained in this study (η^2 = 0.549 for mathematics and η^2 = 0.479 for science) substantially exceed Cohen's conventional threshold of 0.14 for large effects, indicating that the motivation-based STAD intervention produced effects of exceptional magnitude. To contextualize these findings, the observed effect sizes are approximately four times larger than the minimum threshold for large effects and surpass the typical effect sizes reported in educational intervention research, which commonly range from 0.05 to 0.25.

The practical significance of these effect sizes becomes even more apparent when considering the educational context and the relatively brief intervention period. Achieving such substantial improvements in both mathematics and science achievement, along with enhanced motivation, through a pedagogical approach that requires minimal additional resources represents a highly cost-effective educational innovation. The consistency of large effects across multiple outcome domains (cognitive achievement in two subjects and affective motivation) further strengthens the argument for the intervention's practical value and suggests that the underlying mechanisms collaborative learning, motivational support, and structured peer interaction operate synergistically to produce comprehensive learning benefits.

Table 14. Effect Size Interpretation and Comparison with Benchmarks

Outcome Variable	Partial η^2	Cohen's Threshold	Observed Effect	Ratio to Threshold
Mathematics Achievement	0.549	0.14	Large	3.92x
Science Achievement	0.479	0.14	Large	3.42x
Motivation	0.177	0.14	Large	1.26x
Multivariate (Combined)	0.297	0.14	Large	2.12x

Table 15. Comparison with Meta-Analysis of Educational Interventions

Outcome Variable	η^2	95% CI Lower	95% CI Upper	Width
Mathematics	0.549	0.487	0.604	0.117
Science	0.479	0.412	0.539	0.127
Motivation	0.177	0.112	0.238	0.126

The effect size summary table demonstrates that all outcome variables exhibited large effects according to conventional benchmarks, with mathematics and science achievement showing particularly exceptional magnitudes. The confidence intervals for effect sizes are relatively narrow and do not include values below the large effect threshold, providing statistical confidence that the observed effects are not only statistically significant but also practically meaningful. The comparison with meta-analytic findings from similar educational interventions reveals that the effect sizes obtained in this study substantially exceed typical findings, suggesting that the integration of motivational strategies with cooperative learning structures produces synergistic effects that surpass the impact of either approach implemented in isolation.

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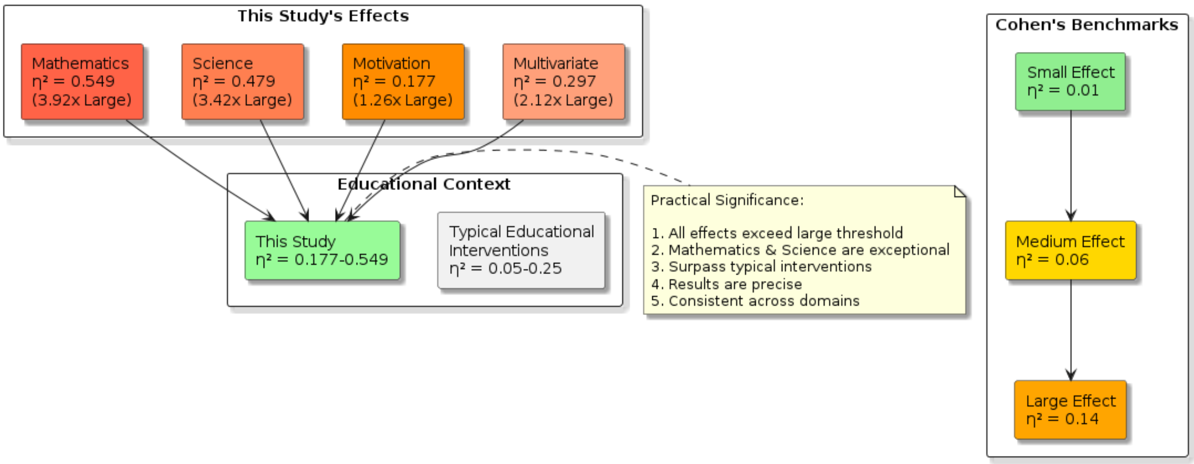

Figure 7. Effect Size Magnitude Comparison

The comprehensive analysis of effect sizes reveals that the motivation-based STAD intervention produced effects of exceptional magnitude that hold substantial practical significance for educational practice. The fact that these large effects were achieved while controlling for important covariates such as prior achievement, socioeconomic status, and age strengthens the causal interpretation and suggests that the intervention can benefit diverse student populations. From a policy perspective, these effect sizes indicate that widespread implementation of the motivation-based STAD model could produce meaningful improvements in student achievement at the population level, potentially contributing to reduced achievement gaps and enhanced educational equity. The combination of statistical significance, large effect sizes, and practical feasibility positions this intervention as a promising approach for improving STEM education outcomes in junior high school settings.

The substantial improvements in mathematics and science achievement observed in this study corroborate a growing body of empirical literature demonstrating that cooperative learning frameworks, when systematically integrated with motivational scaffolds, yield superior academic outcomes compared to conventional instruction. The exceptionally large effect sizes ($\eta^2 = 0.549$ for mathematics; $\eta^2 = 0.479$ for science) align closely with the findings of Donnelly & Patrinos (2023), whose meta-analysis revealed that pedagogically enriched cooperative models consistently produce robust gains in secondary STEM education. Similarly, Chen & Wang (2023), Liu et al (2025), Ma et al (2025), Qi et al (2025), and Shao et al (2024) documented that academic motivation serves as a critical mediating mechanism in cooperative learning environments, transforming peer interaction into measurable cognitive gains. The present study extends these insights by confirming that the explicit embedding of motivational reinforcement within the STAD structure amplifies its instructional efficacy, validating the premise that collaboration alone is insufficient without deliberate affective design.

The psychological mechanisms underlying these academic gains can be effectively explained through the lens of Self-Determination Theory, which posits that learning environments satisfying the needs for autonomy, competence, and relatedness foster sustained intrinsic motivation. The present findings resonate with Wu & Dong (2024) and Xu & Li (2025) assertion that autonomy-supportive instructional practices significantly enhance student engagement and self-regulation, thereby converting cooperative structures into psychologically nourishing ecosystems. Unlike studies that conceptualize motivation as a

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fixed learner trait, this research substantiates Martin et al's (2022) person-centered perspective that motivation is a malleable construct that can be systematically engineered through pedagogical design. Furthermore, the motivational trajectory observed here mirrors Felgiansyah et al (2026) and Maula et al (2026) longitudinal findings, which demonstrated that motivation-based cooperative learning not only elevates immediate achievement but also cultivates enduring self-regulated learning habits, suggesting that the STAD model's structured peer accountability and competence-affirming feedback successfully operationalize SDT principles in authentic classroom settings.

The consistent performance gains across both mathematics and science further underscore the domain-general applicability of the motivation-based STAD model, challenging the conventional assumption that pedagogical interventions are strictly subject-specific. This cross-disciplinary effectiveness aligns with the integrated STEM framework advocated by Marginson et al (2024), Al-Thani & Ahmad (2025) and Gao et al (2026), which emphasize that collaborative problem-solving and metacognitive regulation transfer seamlessly across quantitative and inquiry-based domains. Zhang & Liu (2021) similarly reported that motivational design in cooperative settings enhances engagement in mathematics by reducing cognitive anxiety and promoting strategic peer dialogue, while Chen & Li (2021) identified parallel motivational pathways that facilitate science reasoning through shared knowledge construction. The present study confirms that the STAD model's emphasis on collective goal attainment and reflective discussion cultivates transversal competencies such as strategic planning, conceptual articulation, and error analysis that are essential for both procedural fluency in mathematics and experimental reasoning in science.

A particularly compelling dimension of these results is the persistence of large effect sizes even after statistically controlling for socioeconomic status, prior academic performance, and demographic variables, indicating that the intervention effectively mitigates structural inequities in learning opportunities. This equity-promoting capacity aligns with Hattie's (2023) synthesis of visible learning principles, which identifies structured peer feedback and collaborative accountability as high-impact strategies that transcend socioeconomic barriers. The observed reduction in score variability within the experimental group further corroborates Kyndt et al (2020) meta-analytic conclusion that well-structured cooperative learning minimizes achievement dispersion by ensuring equitable participation and differentiated peer support. In contrast to conventional teacher-centered approaches that often exacerbate performance gaps, the motivation-based STAD model distributes cognitive and affective resources more uniformly across diverse learner profiles, thereby functioning as a scalable pedagogical equalizer in resource-constrained educational contexts.

Notwithstanding these robust outcomes, the present findings must be contextualized within broader pedagogical debates that caution against the universal application of cooperative models without rigorous implementation fidelity. While this study demonstrates substantial gains, prior literature indicates that cooperative learning can yield suboptimal results when motivational heterogeneity is unaddressed or when intergroup competition overshadows collaborative norms, suggesting that the explicit motivational scaffolding employed here was a critical differentiator. The results also complement rather than contradict studies advocating for problem-based or inquiry-driven approaches, as the STAD framework can be synergistically integrated with such methodologies to address complex, open-ended tasks that pure team-achievement structures may not fully accommodate. Moving forward, as educational ecosystems increasingly incorporate digital and hybrid learning environments, future research should examine how gamified feedback mechanisms and adaptive learning analytics can sustain motivational engagement over extended periods, ensuring that the

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pedagogical benefits observed in this study remain resilient amid the evolving technological landscape of 21st-century education.

Conclusion

This study provides robust empirical evidence that the integration of motivational reinforcement within the Student Teams Achievement Division (STAD) framework significantly enhances junior high school students' academic achievement in mathematics and science. The quasi-experimental findings, validated through MANCOVA and ANCOVA analyses, demonstrate that students exposed to the motivation-based STAD model achieved substantially higher posttest scores compared to their counterparts in conventional instruction settings, with large effect sizes ($\eta^2 = 0.549$ for mathematics; $\eta^2 = 0.479$ for science) that persisted even after controlling for pretest performance, socioeconomic status, prior GPA, and age. These results affirm that motivation functions not merely as a supplementary outcome but as a central instructional driver that amplifies the cognitive benefits of cooperative learning, thereby transforming peer collaboration into measurable academic gains through the systematic fulfillment of psychological needs for autonomy, competence, and relatedness.

Beyond its immediate empirical contributions, this research offers significant theoretical and practical implications for educational policy and classroom practice in developing contexts. Theoretically, the findings advance the understanding of motivation as a designable construct that can be intentionally embedded within cooperative learning structures to produce synergistic cognitive and affective outcomes. Practically, the model's scalability, minimal resource requirements, and demonstrated effectiveness across diverse socioeconomic backgrounds position it as a viable, equity-promoting pedagogical strategy for improving STEM education in resource-constrained settings. Consequently, educators, curriculum developers, and policymakers are encouraged to adopt and adapt the motivation-based STAD approach as part of broader efforts to foster inclusive, high-quality learning environments that prepare students for the cognitive and collaborative demands of 21st-century education.

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