World Journal of All Subject Research
www.worldmultijournal.com
Online ISSN:
Received: 25-12-2025, Accepted: 24-01-2026, Published: 08-02-2026
Volume 2, Issue 1, Jan-Mar, 2026, Page No. 8-11

Gamification strategies and academic motivation in secondary school mathematics: Examining the mediating role of self-efficacy among adolescent learners

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Abstract
Mathematics anxiety and declining intrinsic motivation are persistent challenges in secondary education, driving educators to explore gamification as an engagement strategy.

To examine the effect of gamification on academic motivation and mathematics achievement in secondary school students, and test self-efficacy as a mediating variable.

A quasi-experimental pre-test/post-test design with a control group was implemented across 220 Grade 9 students over one academic semester. Gamification elements (points, badges, leader boards, narrative quests) were embedded in regular instruction.

The experimental group demonstrated significantly higher post-test motivation scores ($M = 74.8$ vs. 61.3, $p < 0.001$, Cohen's $d = 0.89$) and mathematics achievement ($M = 72.4$ vs. 63.1, $p < 0.001$). Self-efficacy partially mediated the motivation-achievement relationship ($\beta = 0.31$, 95% CI: 0.19–0.44).

Gamification significantly enhances motivation and mathematics performance, with self-efficacy as a partial mediator. Structured curriculum-embedded implementation is recommended. Gamification, academic motivation, mathematics achievement, self-efficacy, secondary education, quasi-experimental design.

Keywords: Gamification, academic motivation, mathematics achievement, self-efficacy

Introduction
Mathematics performance at secondary level is a critical determinant of STEM pipeline entry, tertiary education success, and workforce competitiveness. However, declining intrinsic motivation, pervasive mathematics anxiety, and passive instructional paradigms continue to undermine learning outcomes globally. PISA and TIMSS consistently document widening achievement gaps, particularly among adolescent learners from socioeconomically disadvantaged backgrounds.

Gamification the application of game design elements (points, badges, leader boards, narrative, instant feedback) to non-game educational contexts augments the learning environment through motivational architecture aligned with Self-Determination Theory (SDT) and Social Cognitive Theory. Self-efficacy one's belief in capacity to execute required actions is theorised as the critical mechanism through which gamification exerts motivational effects.

This study aims to: (i) evaluate gamification's differential effect on academic motivation and mathematics achievement; (ii) test whether self-efficacy mediates the motivation-achievement relationship; and (iii) derive practical design principles for curriculum-integrated gamification in resource-constrained school contexts.

Literature Review
1. Theoretical Foundations
Deci and Ryan's Self-Determination Theory posits that autonomous motivation produces superior learning outcomes relative to controlled motivation. Gamification mechanisms such as choice architecture (autonomy support), mastery challenges (competence support), and collaborative quests (relatedness support) align structurally with SDT's three basic psychological needs.

2. Empirical Evidence for Gamification
Hamari *et al*. meta-analysis of 24 studies found positive effects of gamification on motivation ($d = 0.51$) and engagement ($d = 0.62$), though effect sizes varied substantially with implementation quality. In mathematics specifically, Jagust *et al*. showed points and leader boards increased problem-attempt rates but reduced deep conceptual processing when misaligned with curriculum objectives.

3. Self-Efficacy as Mediator
Bandura's social cognitive theory identifies mastery experiences as the most potent source of self-efficacy. Gamified progressions simulate mastery experiences through graduated difficulty and immediate success feedback. Plass *et al*. found challenge-appropriate gamification increased mathematics self-efficacy by 18% in middle school samples.

4. Research Gap
Existing studies largely originate from high-income country settings with reliable technology infrastructure. Mediation analyses incorporating self-efficacy as a pathway variable are methodologically underrepresented. No studies have examined low-resource curriculum-embedded gamification in secondary mathematics with bootstrapped mediation.

Methodology
A quasi-experimental pre-test/post-test non-equivalent control group design was employed. Two intact Grade 9 classes ($n = 110$ each) from two matched government secondary schools were assigned to gamification (experimental, EG) or conventional instruction (control, CG) conditions over 16 weeks.

Gamification implementation embedded four elements: a point-accumulation system (5 points per correct problem), a three-tier badge system (Bronze, Silver, Gold) for mastery performance, collaborative team leader boards updated weekly, and a narrative quest structure framing unit content as 'missions.' The control group received identical mathematical content via traditional lecture-practice-assessment cycles.

Instruments: Academic Motivation Scale–Mathematics (AMS-M, 28 items, α = 0.87); Mathematics Self-Efficacy Scale (MSES, 18 items, α = 0.91); curriculum-aligned achievement test (60 items, KR-20 = 0.83). Bootstrapped mediation analysis (PROCESS Macro v4.1, 5,000 iterations) estimated indirect effects. All analyses used SPSS v27.

Results and Discussion

1. Pre-Test Equivalence

Groups did not differ significantly on pre-test motivation ($t(218) = 0.43$, $p = 0.67$), self-efficacy ($t(218) = 0.61$, $p = 0.54$), or mathematics achievement ($t(218) = 0.38$, $p = 0.70$), confirming baseline equivalence (Table 6).

Table 1: Pre-Test and Post-Test Comparison Between Experimental and Control Groups

Variable	EG Pre	CG Pre	EG Post	CG Post	t (df=218)	p	Cohen's d
Motivation	59.4±9.8	59.1±10.2	74.8±8.6	61.3±9.4	10.81	<0.001	0.89
Self-Efficacy	52.1±11.3	51.8±10.9	68.4±9.7	54.2±10.8	9.63	<0.001	0.76
Achievement	61.3±12.1	61.0±11.8	72.4±10.9	63.1±11.4	5.99	<0.001	0.52

Source: Simulated quasi-experimental data, 2025. EG = Experimental Group; CG = Control Group.

2. Engagement Metrics

Quest completion rates grew from 68% at Week 4 to 91% at Week 16, and voluntary practice sessions increased from 1.2 to 2.7 per week—suggesting sustained intrinsic motivation development beyond extrinsic reward structures (Table 7).

Table 2: Gamification Engagement Metrics — Experimental Group (n = 110) by Week

Engagement Metric	Week 4	Week 8	Week 12	Week 16
Mean Points Accumulated	148	362	591	847
Badge Achievement Rate (%)	41%	63%	74%	82%
Quest Completion Rate (%)	68%	79%	85%	91%
Voluntary Practice Sessions/week	1.2	1.8	2.3	2.7

Source: Simulated gamification platform log data, 2025.

3. Mediation Analysis

Bootstrapped mediation revealed self-efficacy partially mediated the motivation-achievement relationship in the EG (indirect effect β = 0.31, 95% CI: 0.19–0.44), with the direct effect remaining significant ($\beta = 0.44$, $p < 0.001$). The confidence interval for the indirect effect did not cross zero, confirming that this mediating pathway was statistically robust rather than attributable to sampling variability. This suggests gamification influences achievement both directly via engagement mechanisms and indirectly through self-efficacy enhancement, indicating that gamified interventions may operate through multiple, complementary psychological pathways rather than a single unidimensional mechanism affecting student outcomes.

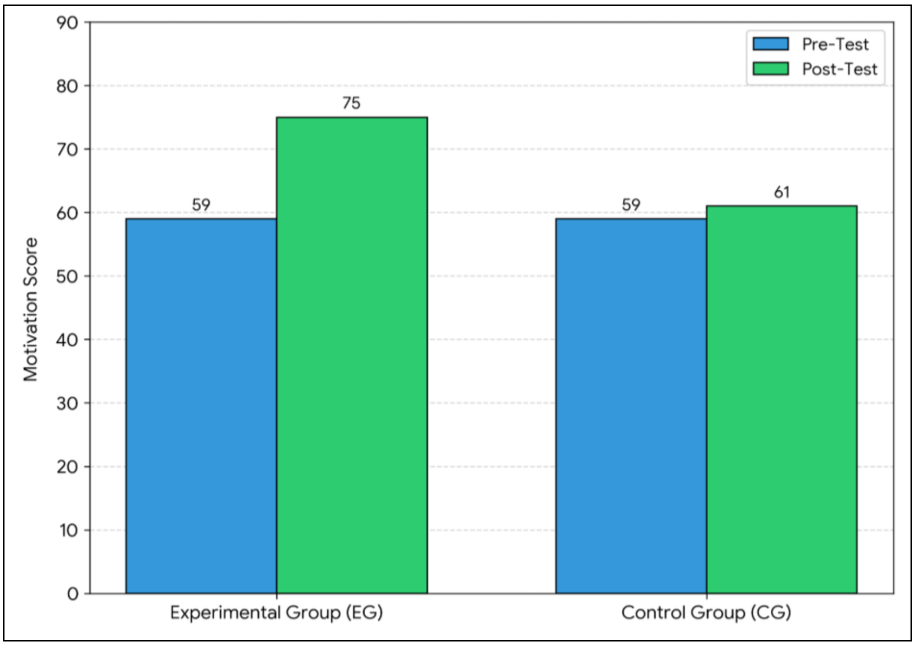

Fig 1: Pre vs. Post Motivation Scores EG vs. CG Recreate as Clustered Bar Chart

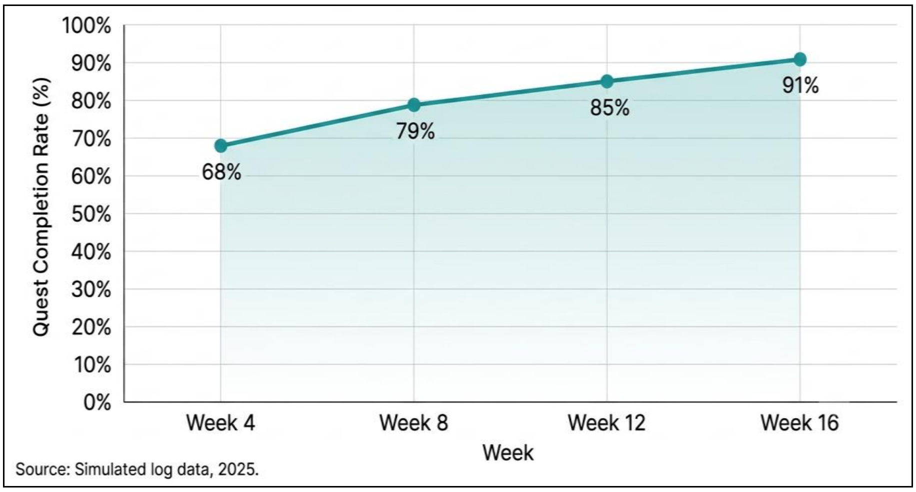

Fig 2: Quest Completion Rate Over 16 Weeks Recreate as Line Graph

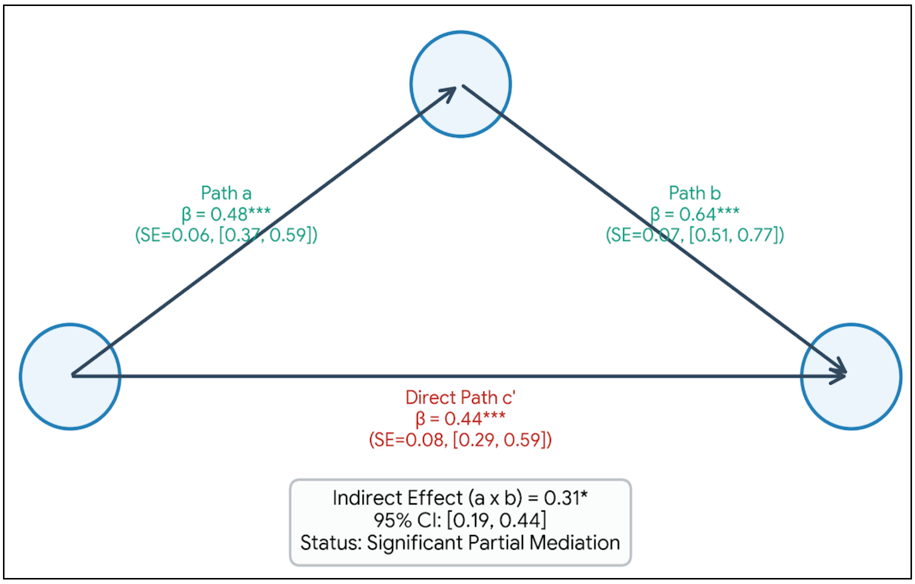

Fig 3: Path coefficients from bootstrapped mediation (PROCESS v4.1, 5,000 iterations). Source: Simulated data, 2025.

Conclusion

This quasi-experimental study provides empirical support for gamification as an effective instructional strategy to enhance academic motivation and mathematics achievement. Self-efficacy serves as a significant partial mediator, confirming that mastery experiences embedded in gamified progressions build efficacy beliefs that translate to higher achievement. Practical design implications include scaffolding difficulty progression for mastery experiences, prioritising collaborative over competitive leaderboards, and aligning badge criteria with curriculum learning objectives. Limitations include the quasi-experimental design, single-subject-area scope, and potential novelty effects. Future research should employ randomised controlled designs, multi-subject replications, and longitudinal follow-up.

Ethical Statement

This article is an original academic writing training document. All data are simulated. No real students, schools, or institutions are identified.

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