

Gamified Teaching Model in Basic Sciences: Impact on Learning Strategies and Academic Motivation of Engineering Undergraduate Students

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ABSTRACT:

Low academic motivation and ineffective learning strategies represent persistent challenges in engineering education, particularly in basic science courses such as Calculus. This study analyzes the impact of a gamified teaching model on learning strategies and academic motivation among undergraduate engineering students at Universidad Cooperativa de Colombia (UCC), Villavicencio campus. A quasi-experimental pretest–posttest design was applied to two groups of 32 students enrolled in Integral Calculus and Differential Calculus. Data were collected using the Motivated Strategies for Learning Questionnaire–Short Form (MSLQ-SF), comprising 40 Likert-scale items across seven dimensions. Results revealed significant improvements following the gamified intervention: active class participation increased by 42%, self-regulated study habits improved by 35%, and interest in course content rose by 40%. Post-intervention data showed that over 84% of students demonstrated enhanced metacognitive awareness, critical thinking, and intrinsic motivation. The findings support the conclusion that structured gamification—integrating points, levels, badges, narrative-driven challenges, and immediate feedback—can effectively transform traditional pedagogical practices in higher education engineering programs, fostering autonomous, meaningful, and emotionally sustainable learning experiences.

Keywords: gamification; academic motivation; learning strategies; engineering education; higher education; quasi-experimental design.

1. Introduction

In recent years, higher education has faced the challenge of transforming its teaching methodologies to respond to the evolving learning

dynamics of students, who increasingly demand active, motivating, and meaningful environments (Deterding et al., 2011; Kapp, 2012). This challenge is particularly acute in engineering

programs, where basic science courses such as Calculus, Physics, and Programming are characterized by high conceptual complexity, elevated failure rates, and widespread student disengagement (Hamari et al., 2014; Yasin & Abbas, 2021).

At an engineering school at a university in Colombia, a recurring problem has been identified: low academic motivation among undergraduate students in foundational courses. This phenomenon not only affects individual performance but also undermines the overall quality of the educational process, contributing to high dropout rates and poor knowledge retention (Amórtegui, 2021). Traditional lecture-based approaches, centered on content transmission and summative assessment, have proven insufficient to foster deep comprehension and sustained engagement in these disciplines (Morales et al., 2023; Ojeda & Zaldívar, 2023).

Gamification—defined as the application of game-design elements and mechanics in non-game contexts—has emerged as a promising pedagogical strategy to address these challenges (Detterding et al., 2011; Zichermann & Cunningham, 2011). When thoughtfully integrated into educational settings, gamification can enhance intrinsic motivation, promote active participation, and strengthen cognitive and metacognitive learning strategies (Deci & Ryan, 1985; Ryan & Deci, 2000). Key mechanisms include challenge-based learning, immediate feedback, symbolic rewards such as badges and points, progression systems, and engaging narratives that transform traditional classroom experiences (Kapp, 2012; Oriol, 2024).

From a theoretical standpoint, this study is grounded in the Self-Determination Theory (SDT) proposed by Deci and Ryan (1985), which posits that intrinsic motivation flourishes when three basic psychological needs are satisfied: autonomy, competence, and relatedness. Gamified environments can address all three by offering

students choices in challenges (autonomy), providing immediate feedback and progressive difficulty levels (competence), and fostering collaboration through team-based missions (relatedness). Additionally, the Achievement Motivation Theory (Atkinson, 1957) and the Goal Orientation Theory (Dweck & Leggett, 1988) provide complementary frameworks for understanding how gamification can shift students from performance-avoidance orientations toward mastery-oriented mindsets.

Despite the growing body of literature on gamification in higher education (Balón et al., 2024; López et al., 2024; Martín et al., 2024; Orozco, 2025; Sandoval & Seguel, 2025), empirical studies specifically targeting basic science courses in Latin American engineering programs remain scarce. Most existing interventions consist of isolated applications of game-like tools without a coherent pedagogical structure or contextual adaptation (Valencia & Orellana, 2019; Caballero et al., 2019). This gap justifies the need for a comprehensive, context-specific gamified model that integrates curricular alignment, motivational design, and systematic evaluation.

The present study aims to analyze the impact of a gamified teaching model on learning strategies and academic motivation among undergraduate engineering students at UCC, Villavicencio campus. Specifically, it seeks to: (1) characterize the motivational profiles and cognitive learning strategies of students prior to intervention; (2) implement gamified activities in basic science courses; and (3) evaluate the changes in learning strategies and intrinsic motivation following the intervention. The findings are expected to contribute empirical evidence supporting the use of structured gamification as an innovative and effective tool for transforming educational practices in engineering higher education.

2. Materials and Methods

2.1. Research Design

This study adopted a quantitative, quasi-experimental pretest–posttest design applied to a single group, given the logistical constraints of the educational setting that precluded random assignment (Creswell, 2014). The design enabled the evaluation of changes in the dependent variables—learning strategies and academic motivation—attributable to the gamified intervention (independent variable) by comparing measurements taken before and after implementation.

2.2. Participants

The study population consisted of undergraduate engineering students enrolled in basic science courses at the School of Engineering of a university in Colombia during the 2025 academic year. A purposive, non-probabilistic sample was selected based on the following inclusion criteria: (a) enrollment in Integral Calculus or Differential Calculus; (b) regular class attendance; (c) voluntary participation with informed consent; and (d) availability to complete all study phases.

The final sample comprised two groups: Group 1 ($n = 32$) enrolled in Integral Calculus and Group 2 ($n = 32$) enrolled in Differential Calculus. Students who had previously completed the target courses or who withdrew during the semester were excluded.

2.3. Instruments

Data were collected using the Motivated Strategies for Learning Questionnaire–Short Form (MSLQ-SF), validated for Colombian university students by Sabogal et al. (2011). The instrument consists of 40 Likert-scale items (1 = Never to 5 = Always) organized into seven categories: interest, persistence, self-evaluation, collaboration, class participation, study habits, and academic productivity. The questionnaire was administered at two time points: at the beginning of the

semester (pretest) and at the conclusion of the gamified intervention (posttest).

2.4. Gamified Intervention

The intervention, named *"Ingenia tu Ruta"* (Engineer Your Path), was implemented over a 16-week academic period, comprising 10 gamified sessions integrated into the regular course curriculum. The gamified model incorporated the following elements:

- **Points system:** Students earned points for attendance, active participation, timely assignment submission, and challenge completion.
- **Progression levels:** Four tiers—Novice, Apprentice, Advanced, and Master—provided visible markers of advancement.
- **Symbolic rewards:** Digital badges and recognitions were awarded for goal achievement, outstanding participation, and continuous improvement.
- **Narrative-driven challenges:** Thematic missions based on real-world engineering problems (e.g., "Save the city through sustainable engineering solutions" or "Design a functional structure using mathematical and physical principles").
- **Immediate feedback:** Continuous formative assessment through interactive quizzes and progress dashboards on virtual platforms.
- **Collaborative dynamics:** Team-based tournaments and cooperative problem-solving activities.

Digital platforms such as Moodle, Genially, and Kahoot were used to deliver gamified content and track student progress.

2.5. Data Analysis

Quantitative data from the MSLQ-SF were coded numerically and analyzed using Microsoft Excel. Descriptive statistics (means, percentages) were computed for each item and dimension. Pretest and posttest results were compared to identify

changes attributable to the intervention. Additionally, official academic records were reviewed to triangulate self-reported data with objective performance indicators.

2.6. Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants. The research protocol was approved by the institutional ethics committee of university of Colombia. Participation was voluntary, and data were anonymized to ensure confidentiality.

3. Results

3.1. Pretest Results: Integral Calculus (Group 1, $n = 32$)

The pretest established a baseline of students' motivational profiles and learning strategies prior to the gamified intervention. Key findings are summarized below.

Adaptability and study habits. Students demonstrated a moderate-to-high willingness to adapt their study methods ($M = 3.66$), though weekly study routines were not fully consolidated ($M \approx 3.6$). The use of organizational strategies such as summarizing ($M = 2.84$) and underlining ($M \approx 3.0$) was infrequent, suggesting a predominance of passive or mechanical study approaches.

Critical thinking and metacognition. The ability to evaluate theories based on evidence ($M \approx$

3.0–3.5) and to identify comprehension gaps ($M = 3.8$) reflected an intermediate level of critical and metacognitive engagement. Students occasionally questioned conclusions ($M = 3.3$) and sought alternative interpretations, but these practices were not yet systematic.

Motivation. Intrinsic motivation indicators were moderately positive: students expressed genuine interest in challenging material ($M \approx 3.9$), valued deep comprehension ($M \approx 4.0$), and considered the course content useful (high mean). However, anxiety-related items revealed significant emotional barriers: 4.03/5 for fear of failure consequences, 4.0/5 for test-related nervousness, and 4.0/5 for physiological anxiety symptoms (rapid heartbeat during exams).

Self-regulation. Goal-setting during study sessions ($M \approx 3.3$ –3.5) and time management ($M = 3.4$) were moderate, while difficulty adapting to study schedules ($M \approx 3.1$) and avoidance of challenging content ($M = 2.6$, reverse-scored) indicated areas requiring pedagogical intervention.

3.2. Posttest Results: Integral Calculus (Group 1, $n = 32$)

Following the gamified intervention, substantial improvements were observed across all measured dimensions. Table 1 presents the percentage of students responding positively (i.e., "Almost always" or "Always") to each item.

Table 1. Posttest results for Integral Calculus group ($n = 32$): Percentage of positive responses.

Item	Description	% Positive
1	Adapts study methods to course requirements	96.88
2	Maintains weekly reading and assignment routines	84.38
4	Relates readings to prior knowledge	93.76
6	Critically evaluates theories and evidence	87.00
7	Seeks strategies when confused	87.00
8	Studies in a concentration-friendly environment	93.75
9	Persists academically despite disinterest	93.75
10	Prefers challenging material	84.38

11	Considers course material useful	90.63
13	Summarizes main ideas	75.00
14	Reviews notes for key ideas	84.38
15	Comprehends purpose beyond memorization	78.13
16	Genuine interest in topics	84.38
19	Satisfaction from deep comprehension	93.75
22	Connects readings with class concepts	87.50
24	Relates learning to personal ideas	87.50
25	Identifies poorly understood concepts	84.38
28	Considers understanding the course important	96.88
30	Applies ideas in presentations and debates	84.38
31	Questions assertions and seeks alternatives	78.13
32	Self-questions to verify comprehension	84.38
40	Organizes confusing notes	87.50

Notable improvements included a dramatic increase in study method adaptability (from $M = 3.66$ to 96.88% positive), summarization practices (from $M = 2.84$ to 75% positive), and critical evaluation of evidence (from $M \approx 3.0$ to 87% positive). However, anxiety-related items remained elevated: 71.88% still feared failure consequences (Item 12), 62.50% reported test

anxiety (Item 21), and 59.38% experienced physiological symptoms (Item 29), indicating that emotional regulation requires continued attention.

3.3. Posttest Results: Differential Calculus (Group 2, $n = 32$)

The Differential Calculus group showed comparable improvements. Table 2 summarizes key findings.

Table 2. Posttest results for Differential Calculus group ($n = 32$): Percentage of positive responses.

Item	Description	% Positive
1	Adapts study methods	81.00
4	Relates readings to prior knowledge	86.00
5	Uses underlining for organization	79.00
6	Seeks evidence for theories	78.00
7	Returns to text when confused	84.00
10	Prefers challenging material	75.00
11	Considers material useful	81.00
13	Summarizes main ideas	73.00
15	Reflects on what to learn	81.00
19	Satisfaction from deep understanding	84.00

22	Connects readings and class concepts	79.00
25	Identifies comprehension gaps	84.00
28	Values understanding the subject	82.00
32	Self-questions for comprehension	82.00
36	Develops own ideas from course material	75.00
40	Organizes confusing notes	86.00

3.4. Summary of Key Improvements

Across both groups, the gamified intervention produced the following aggregate improvements

- **Active class participation** increased by approximately 42%.
- **Self-regulated study habits** (planning, time management, note organization) improved by approximately 35%.
- **Interest in course content** and voluntary participation in additional activities rose by approximately 40%.
- **Critical thinking and metacognitive strategies** showed consistent gains, with post-intervention positive response rates exceeding 75% on most items.
- **Academic performance** indicators (course grades and pass rates) improved, though detailed grade data are reported elsewhere.

4. Discussion

The findings of this study provide robust empirical evidence that a structured gamified teaching model can significantly enhance learning strategies and academic motivation among engineering undergraduate students in basic science courses. These results align with and extend previous research on gamification in higher education (Hamari et al., 2014; Ibáñez et al., 2019; Zainuddin et al., 2020; Balón et al., 2024; Orozco, 2025).

Impact on learning strategies. The most pronounced improvements were observed in

cognitive and metacognitive strategies. Prior to the intervention, students relied predominantly on passive study methods (e.g., memorization, minimal summarization). Following gamification, there was a marked shift toward active elaboration, critical evaluation of evidence, self-questioning, and knowledge transfer—strategies associated with deep, meaningful learning (Weinstein & Mayer, 1986; Ausubel, 1963). The gamified environment, with its progressive challenges and immediate feedback loops, appears to have scaffolded the development of self-regulated learning competencies that traditional lecture formats failed to cultivate.

Impact on motivation. Consistent with Self-Determination Theory (Deci & Ryan, 1985; Ryan & Deci, 2000), the gamified model strengthened intrinsic motivation by satisfying students' needs for autonomy (choice of challenges), competence (progression levels and badges), and relatedness (collaborative missions). The increase in students' preference for challenging material (84.38% and 75% in Groups 1 and 2, respectively) and their reported satisfaction from deep comprehension (93.75% and 84%) suggests a shift from extrinsic, grade-driven motivation toward genuine intellectual curiosity—a finding corroborated by recent studies (Chávez & García, 2022; Pacheco et al., 2021; Donayre et al., 2024).

Persistent challenges: Test anxiety. Despite overall gains, anxiety-related indicators remained elevated in both groups. Approximately 60–72%

of students continued to report fear of failure, test nervousness, and physiological stress symptoms. This finding underscores the limitation of gamification as a standalone intervention for emotional regulation and suggests the need for complementary psychoeducational support, formative assessment practices that normalize error, and mindfulness-based strategies (Schladitz et al., 2024; Cortez & Alchundia, 2024).

Contextual relevance. The results are particularly significant given the Latin American higher education context, where engineering programs face structural challenges including limited technological infrastructure, large class sizes, and socioeconomic barriers (Amórtegui, 2021; Alonso et al., 2021; Villamar & Sánchez, 2024). The *"Ingenia tu Ruta"* model demonstrates that gamification, when contextually adapted and pedagogically grounded, can serve as an equitable and scalable innovation strategy.

Limitations. This study has several limitations. First, the absence of a control group limits causal inference; observed improvements may be partially attributable to maturation or Hawthorne effects. Second, the sample size ($n = 64$) is relatively small, constraining generalizability. Third, the reliance on self-reported data introduces potential response bias, although triangulation with academic records partially mitigates this concern. Future research should employ randomized controlled designs with larger, multi-institutional samples and longitudinal follow-up to assess the sustainability of observed effects.

5. Conclusions

This study demonstrates that the implementation of a structured gamified teaching model in basic science courses produces significant positive effects on learning strategies and academic motivation among engineering undergraduate students. The integration of game elements—points, levels, badges, narrative-driven challenges, and

immediate feedback—within a coherent pedagogical framework fostered the development of metacognitive skills, critical thinking, self-regulated study habits, and intrinsic motivation.

The findings support the conclusion that gamification, when designed with clear pedagogical objectives and contextual sensitivity, transcends its role as a mere motivational accessory to become a transformative educational strategy. However, the persistence of test anxiety highlights the need for holistic interventions that combine gamification with psychoeducational support and formative assessment reform.

The *"Ingenia tu Ruta"* model offers a replicable framework for higher education institutions seeking to innovate their engineering curricula. Future research should explore its scalability across disciplines, its long-term impact on retention and graduation rates, and its potential integration with emerging technologies such as artificial intelligence and adaptive learning platforms.

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