

Racing to Learn: A Formula 1–Inspired Gamification Framework that Sustains Motivation Through Repeated Competitive Cycles

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Abstract: Gamification is increasingly used in higher education to support student engagement; however, the effects of narrative-driven competitive frameworks on academic performance remain underexplored. This study examines a Formula 1 (F1)–inspired gamification experience implemented in an undergraduate Internet of Things (IoT) course. Students were randomly assigned to one of five racing teams and participated in three competitive "races" over a ten-week term. Progress was quantified as distance (in meters), accumulated through optional exercises, collaborative tasks, additional coding functionalities, quizzes, and attendance. The gamification framework was grounded in Self-Determination Theory, aiming to support students' autonomy, competence, and relatedness through multiple engagement pathways, continuous feedback, and team-based competition. To enhance immersion, a Unity-based interface was developed to dynamically visualize team progress, displaying race cars moving across circuits. Symbolic, social, and academic rewards were awarded after each race. A quasi-experimental design compared outcomes between a gamified group and a non-gamified control group under equivalent instructional conditions. Results indicate that students in the gamified condition achieved slightly higher academic outcomes, particularly on the final exam. However, an independent samples t-test showed that this difference was not statistically significant ($t(54) = 1.74$, $p = 0.087$), although a small-to-moderate effect size was observed ($d = 0.43$). Within the gamified group, a strong positive correlation was found between cumulative gamified engagement and final exam performance ($r = 0.81$, $R^2 = 0.65$), suggesting a meaningful association between participation and learning outcomes. The use of repeated competitive cycles with progress resets appeared to sustain motivation while mitigating performance stratification. Overall, the findings suggest that narrative-driven competitive gamification may support engagement and improve academic outcomes when carefully aligned with pedagogical objectives. The proposed framework offers a structured and replicable model for gamification in higher education. Future research should explore the scalability of this approach across diverse disciplines and examine its long-term impact on academic achievement.

Keywords: Gamification, Narrative-driven competition, Internet of Things (IoT), Educational Innovation, Higher education

1. Introduction

In recent years, gamification has gained significant attention in higher education as a strategy to enhance student engagement, motivation, and academic performance. By integrating game elements such as points, competition, and rewards into educational contexts, instructors aim to foster more active and self-directed learning experiences. This trend has been particularly relevant in engineering education, where maintaining student engagement in technically demanding courses remains an ongoing challenge.

Despite its growing adoption, the effectiveness of gamification varies considerably depending on its design. While many implementations rely on isolated elements such as points or badges, recent research suggests that more complex approaches—particularly those incorporating narrative structures and sustained competitive dynamics—may produce stronger motivational effects. However, empirical evidence examining the impact of narrative-driven competitive gamification frameworks on academic performance remains limited, especially in higher-education STEM contexts.

This study addresses this gap by exploring a gamified learning experience inspired by Formula 1 (F1) racing, implemented in a third-semester undergraduate Internet of Things (IoT) course within a Computer Science engineering program at Tecnológico de Monterrey. The course is mandatory and has traditionally posed challenges for sustained engagement, particularly in activities that require consistent practice, such as programming and system integration.

The proposed gamification design integrates a narrative-driven competitive framework in which students are organized into teams and participate in multiple "races" throughout the academic term. Unlike static gamification models, this approach incorporates iterative competition cycles, performance-based progression, and visual feedback through a custom-built interface. The design aims not only to increase participation but also to encourage continuous effort, collaboration, and self-regulated learning behaviours.

To evaluate the effectiveness of this approach, a quasi-experimental design was employed, comparing a gamified group with a non-gamified control group under equivalent learning conditions. The study examines

both academic performance outcomes and the relationship between gamified engagement and final assessment results.

The main objective of this research is to analyse whether a narrative-driven competitive gamification framework can enhance engagement and improve academic performance in an engineering course at the higher-education level. Additionally, the study seeks to determine the extent to which participation in gamified activities is associated with measurable learning outcomes.

2. Literature Review and Theoretical Framework

2.1 Gamification in Higher Education

Gamification has been extensively studied as a pedagogical strategy to enhance student engagement by integrating game mechanics into non-game contexts, especially in educational settings. In higher education, its application has demonstrated positive effects on participation, persistence, retention, and, in some cases, academic performance (Deterding et al., 2011; Hamari et al., 2014). However, findings remain inconsistent, largely due to variations in design methodologies and the degree to which gamification elements are meaningfully integrated into the learning process (Seaborn and Fels, 2015).

Early implementations of gamification often relied on isolated mechanics such as points, badges, and leaderboards. While these components can provide short-term motivational boosts, their effectiveness diminishes when they are detached from broader pedagogical objectives (Hanus and Fox, 2015). Recent research advocates holistic gamification designs in which multiple elements interact to support sustained engagement and learning outcomes (Toda et al., 2019).

2.2 Self-determination Theory and Motivation

Self-Determination Theory (SDT) serves as a foundational framework for understanding the motivational impact of gamification. This framework states that human motivation is driven by the fulfilment of three core psychological needs: autonomy, competence, and relatedness (Deci and Ryan, 2000).

Gamification can address these needs in several ways (Sailer et al., 2017):

- Autonomy is supported through optional challenges, diverse pathways for progression, and freedom of choice.
- Competence is reinforced via feedback systems, incremental achievements, and visible progress indicators.
- Relatedness is promoted through social interactions, whether collaborative or competitive.

Research underscores the importance of aligning gamification designs with SDT principles, as environments that foster intrinsic motivation tend to yield more meaningful and sustained engagement than those that rely on extrinsic rewards (Ryan and Deci, 2020). This highlights the importance of designing gamification experiences that support intrinsic motivation rather than merely incentivizing participation.

2.3 Narrative and Competition in Gamification Design

Among the various design dimensions of gamification, narrative and competition are two pivotal elements that enhance engagement and immersion. Narratives provide contextual meaning to tasks, transforming fragmented activities into part of a coherent experience and enhancing immersion (Nicholson, 2015). By embedding tasks within a story, students are more likely to perceive their efforts as purposeful and engaging.

Competition can be a strong motivator by introducing clear goals, social comparison, and performance pressure. However, its effectiveness depends on careful implementation. Poorly designed competitive systems risk alienating lower-performing students, while structured competition can foster resilience and sustained participation (Burguillo, 2010).

Recent studies suggest that combining narrative and competition within a structured framework can amplify their individual effects, although empirical evidence in higher education contexts remains limited (Dichev and Dicheva, 2017).

2.4 Gamification in Engineering and Computer Science Education

Engineering and computer science education pose unique challenges, including low engagement with programming tasks, inconsistent practice habits, and high cognitive load. Studies have shown that gamified

approaches can increase participation in coding exercises and improve learning outcomes (Ibáñez et al., 2014; Barata et al., 2013).

Nonetheless, many implementations remain limited to point-based systems or short-term interventions, lacking the depth needed for sustained engagement. There is a need for more structured, longitudinal gamification designs that align closely with course objectives and foster continuous motivation (Subhash and Cudney, 2018). Additionally, few studies provide quantitative evidence linking gamified engagement to academic performance.

2.5 Research gap

Despite the growing body of literature on gamification in education, several critical gaps remain unaddressed, particularly in higher education contexts. These gaps highlight the need for further investigation into specific gamification strategies, their implementation, and their measurable impact on academic outcomes. Below, we outline the most prominent areas requiring further exploration:

2.5.1 Limited research on narrative-driven gamification frameworks

Narrative-driven gamification, which integrates storytelling elements to provide contextual meaning to tasks, has shown promise in enhancing engagement and immersion (Nicholson, 2015). However, most studies focus on isolated game mechanics rather than cohesive narrative frameworks. While narratives can transform fragmented activities into meaningful experiences, empirical evidence on their effectiveness in higher education settings remains scarce (Dichev and Dicheva, 2017). There is a need for structured designs that combine narratives with other gamification elements to sustain engagement over extended periods.

2.5.2 Insufficient empirical evidence on structured competition

Competition is a widely used gamification strategy that can motivate students through social comparison and performance pressure (Burguillo, 2010). However, poorly implemented competitive systems can have negative effects, such as discouraging lower-performing students or exacerbating performance disparities (Hanus and Fox, 2015). While structured competition frameworks, such as iterative cycles with periodic resets, have the potential to mitigate these issues, empirical studies examining their long-term impact on student engagement and academic performance are limited.

2.5.3 Limited quantitative evidence on narrative-driven competitive gamification

Although gamification has been shown to increase participation and engagement in educational activities (Hamari et al., 2014), evidence regarding its impact on measurable academic outcomes remains limited. Existing studies have frequently relied on qualitative observations and self-reported measures (Seaborn and Fels, 2015), while comparatively fewer have employed objective academic performance indicators. Consequently, further quantitative research is needed to better understand the relationship between gamified engagement and learning outcomes and to strengthen the empirical foundation of gamification in higher education.

2.5.4 Limited application of gamification in STEM education

While gamification has been extensively studied in general education contexts, its application in STEM fields, particularly engineering and computer science, is less developed (Ibáñez et al., 2014). These disciplines face unique challenges, such as high cognitive load and low engagement in technical tasks, which require tailored gamification designs. Few studies provide longitudinal data on the effectiveness of gamification in STEM courses, leaving a gap in understanding how sustained engagement can impact learning outcomes.

2.5.5 Need for multidimensional frameworks

Most gamification studies focus on single design elements, such as feedback systems or leaderboards, without considering how multiple elements interact to produce holistic effects (Toda et al., 2019). Multidimensional frameworks that combine narrative, competition, collaboration, and real-time feedback are rarely explored, despite their potential to address diverse motivational needs. Research on such frameworks would provide valuable insights into how gamification can be optimized to support both engagement and academic performance.

2.6 Contribution of this Study and Research Questions

The literature suggests that gamification can positively influence motivation and engagement, particularly when designed according to Self-Determination Theory principles. Previous studies have highlighted the value of competition, collaboration, feedback systems, and narrative elements; however, the effects of combining these mechanisms within iterative competitive cycles remain underexplored. In particular, limited evidence exists regarding how repeated competition with periodic resets influences participation patterns, academic performance, and performance distribution among students.

This study contributes a structured gamification framework characterized by:

- Iterative competitive cycles with periodic resets to sustain motivation.
- Decoupling gamified team structures from academic project teams to balance competition and collaboration.
- Real-time visual feedback through a custom-developed Unity-based interface to enhance immersion.

Grounded in Self-Determination Theory, the framework seeks to support autonomy through diverse engagement pathways, competence through continuous feedback and measurable progress, and relatedness through team-based competition.

Based on the gaps identified in the literature and the proposed framework, the following research questions were formulated:

- RQ1: To what extent does narrative-driven competitive gamification influence student participation in optional learning activities?
- RQ2: What is the relationship between gamified engagement and academic performance?
- RQ3: How do repeated competitive cycles affect performance distribution?

3. Methodology

3.1 Research Design

This study employed a quasi-experimental design to evaluate the impact of a narrative-driven competitive gamification framework on student engagement and academic performance. Two existing groups of undergraduate students enrolled in an Internet of Things (IoT) course were compared: one that experienced a gamified intervention and one that followed a non-gamified instructional approach.

Consistent with the quasi-experimental nature of the study, participants were not randomly assigned to the experimental and control conditions. Instead, pre-existing course groups were used to preserve the normal organization of the course.

Both groups received equivalent instructional content, learning objectives, assessments, and teaching conditions, allowing a controlled comparison of the gamification intervention. Although instructional conditions were carefully controlled, the use of pre-existing groups limits the ability to draw definitive causal conclusions from the observed differences between groups.

Within the gamified group, students were randomly assigned to one of five Formula 1-inspired teams to support balanced competition throughout the intervention.

3.2 Course Context

The study was conducted in a mandatory third-semester undergraduate IoT course within a Computer Science engineering program at Tecnológico de Monterrey (located in Mexico). The course spanned a ten-week academic term and integrated theoretical instruction with practical implementation.

Students worked in self-selected teams of approximately five members to design and develop an IoT solution. Projects required integrating sensing hardware, data processing, and wireless communication, culminating in a final presentation and a functional demonstration.

Assessment components included quizzes, homework assignments, practical exercises, and a final project. In addition, optional learning activities—such as extended exercises, supplementary problem sets, and additional coding tasks—were offered to encourage deeper engagement and allow students to earn additional points toward their overall performance.

3.3 Participants

A total of 56 undergraduate students participated in the study. The gamified group (G1) consisted of 27 students, while the non-gamified group (G2) included 29 students. All participants were enrolled in the same academic program and at the same course level, ensuring comparable academic backgrounds and prior knowledge. No significant differences in course content, assessment criteria, or instructional delivery were present between groups.

3.4 Group Condition

Two instructional conditions were implemented:

- Gamified Group (G1): Students experienced a Formula 1–inspired gamification framework incorporating narrative elements, team-based competition, visual progress tracking, and structured rewards. Progress was quantified using a point system translated into distance within a racing metaphor, with multiple competitive cycles conducted throughout the term.
- Non-Gamified Group (G2): Students were offered the same optional learning activities and followed identical course content, schedule, and assessment structure, but without gamification elements, narrative framing, or competitive dynamics.

Both groups were taught by the same instructors, using the same materials and evaluation criteria, to minimize instructional variability.

3.5 Data Collection

Data were collected from multiple sources to evaluate both engagement and academic performance. These included:

- Scores from quizzes, assignments, and final examinations
- Accumulated points from optional learning activities (gamified group)
- Final course grades

In the gamified condition, additional data were collected from the gamification system, including cumulative progress metrics for each team.

3.6 Data Analysis

To assess the impact of the gamification intervention, academic performance outcomes were compared between groups using descriptive statistics. An independent samples t-test was conducted to evaluate differences in final exam scores between the gamified and control groups. Cohen's *d* was calculated as a measure of effect size by dividing the difference between group means by the pooled standard deviation, allowing the practical significance of observed differences to be assessed independently of statistical significance.

Additionally, a Pearson correlation analysis was conducted to examine the relationship between accumulated gamified engagement and final exam performance within the gamified group. The strength of this relationship was further evaluated using the coefficient of determination (R^2).

4. Gamification design: Formula 1 Experience

4.1 Narrative Framework and Team Assignment

Students in the gamified condition were randomly assigned to one of five teams—Ferrari, Aston Martin, Red Bull, Mercedes, or McLaren—independent of their academic project teams. This separation ensured that the gamified layer functioned as a parallel motivational system.

The Formula 1 narrative provided a coherent thematic structure, enhancing immersion and contextualizing progress within a competitive environment.

4.2 Race Structure

The course was divided into three competitive cycles (Figure 1):

- Race 1: Miami
- Race 2: Singapore
- Race 3: Monaco

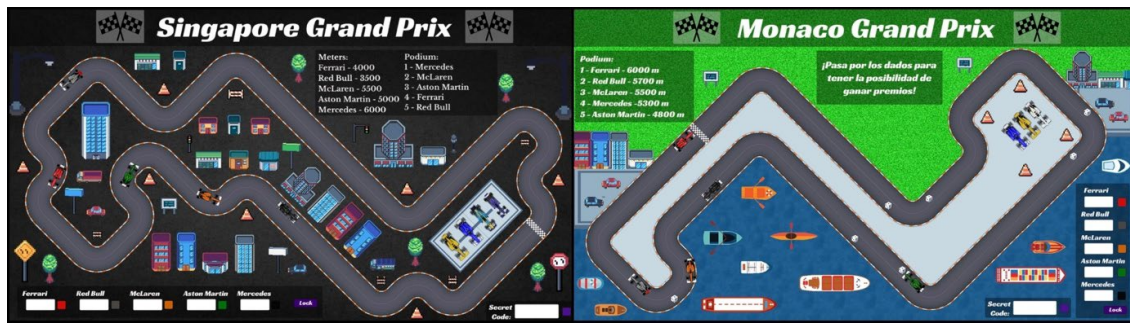


Figure 1: Races 2 and 3 Unity-based interfaces

At the conclusion of each race, all teams' progress was reset to zero. This reset mechanism was designed to maintain motivation and reduce long-term performance gaps.

4.3 Game Mechanics and Progression

Team advancement was quantified in meters, accumulated through:

- Optional activities
- Team tasks
- Additional coding features
- Attendance

Point allocation was intentionally balanced to prevent any single activity type from dominating progression and to ensure sustained engagement across multiple learning tasks.

5. Rewards and Feedback

Top teams were recognized through symbolic, social, and academic rewards. A Unity-based interface provided real-time visual feedback by displaying race progress. Each active race was made available to students through a web application, allowing them to continuously monitor the performance of each team. Whenever a team earned meters to advance, these were applied during class time, triggering an animation in which the corresponding team's car progressed along the track.

5.1 Technological Implementation

The system dynamically updated progress and displayed racetracks for each competition. As illustrated in Figure 2, the winning team is depicted during the award ceremony following the third race; in the background, the support platform (Unity-based) used to track the performance of each team is also visible.



Figure 2: The winning team at the award ceremony following the third race

6. Results

6.1 Academic Performance

Students in the gamified group achieved slightly higher overall performance, particularly on the final exam (Figure 3). An independent samples t-test (assuming equal variances) comparing final exam scores between the gamified group (mean = 89.56, standard deviation = 7.93) and the control group (mean = 84.97, standard deviation = 11.61) indicated that the difference was not statistically significant ($t(54) = 1.74$, $p = 0.087$). However, a small-to-moderate effect size was observed (Cohen's $d = 0.46$). These results suggest a consistent directional effect in favour of the gamified condition across multiple performance indicators.

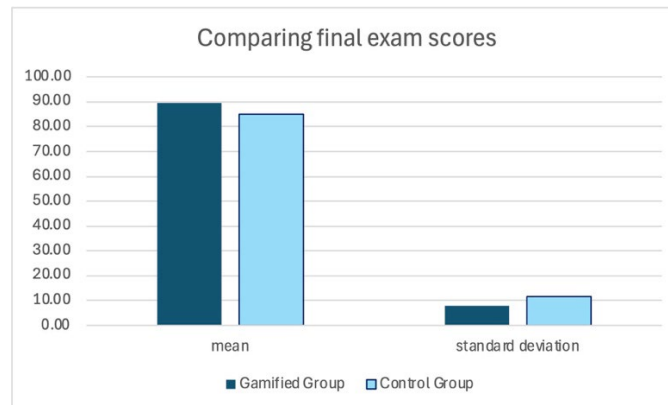


Figure 3: Comparing final exam scores between groups

6.2 Gamified Engagement and Performance

A strong positive correlation was observed between gamified engagement and final exam performance ($r = 0.81$, $R^2 = 0.65$). This relationship suggests that higher participation in optional activities was associated with improved academic outcomes (Figure 4). However, this relationship does not imply causation, as higher-performing students may have been more likely to engage more frequently.

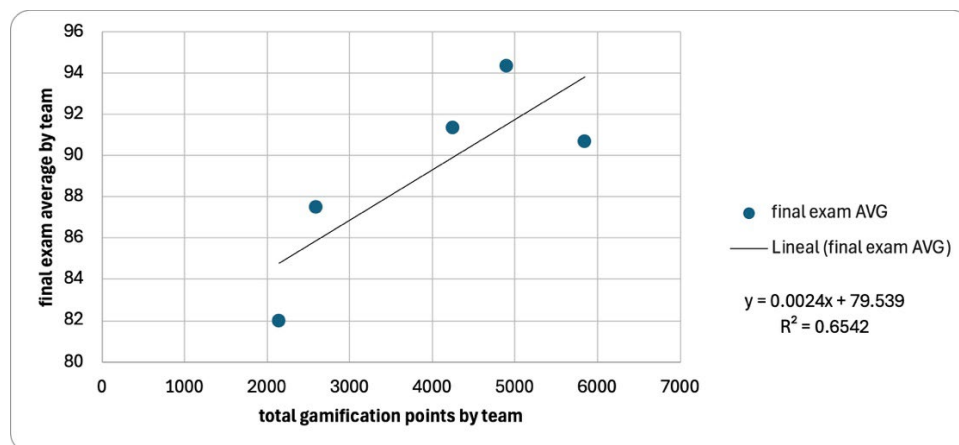


Figure 4: Correlation between gamified engagement and final exam performance

6.3 Participation and Engagement

The gamified group demonstrated consistently higher participation in optional activities. The use of repeated races with resets allowed lower-performing teams to improve over time.

7. Discussion

The findings of this study highlight several important insights into the design and implementation of narrative-driven competitive gamification frameworks in higher education. Increased participation suggests that the gamified design successfully motivated students to engage in activities beyond mandatory requirements, demonstrating its potential to enhance voluntary involvement. Furthermore, the strong positive correlation

observed between engagement and performance indicates that the gamified activities were meaningfully aligned with learning objectives, although causality cannot be established.

7.1 Impact of Resets on Motivation and Equity

One of the most notable features of the framework was the use of iterative competitive cycles with periodic resets. This design element appeared to play a critical role in sustaining motivation across teams and mitigating long-term disparities in performance. By reintroducing opportunities for success at regular intervals, the reset mechanism allowed students to "restart" their progress, reducing the negative effects often associated with cumulative competitive systems, such as performance stratification and disengagement among lower-performing participants. Although the observed differences in academic performance between the gamified and control groups were not statistically significant, the effect size and engagement patterns suggest that the framework may positively influence learning outcomes over time.

7.2 Design Implications

Beyond the specific context of this study, the findings point toward a broader design implication for gamification design in educational settings. Iterative competitive structures with periodic resets may function as a motivational equalizer, enabling sustained engagement across heterogeneous performance levels while preserving competitive tension. This approach contrasts with traditional leaderboard-based gamification systems, which often reinforce early advantages and discourage students who fall behind. By providing multiple opportunities for mastery and success, reset mechanisms can level the playing field and encourage continued participation among all students, regardless of their initial performance.

7.3 Theoretical Insights from Self-determination Theory

From a self-determination theory perspective (Deci and Ryan, 2000), the reset mechanism may reinforce perceptions of competence by providing repeated opportunities for mastery, while the team-based competitive structure sustains relatedness over time. Students are more likely to feel capable and motivated when they perceive that their efforts can lead to tangible achievements, even if they struggled in earlier phases of the gamified experience. Additionally, the team-based competitive structure sustained relatedness by fostering collaborative and competitive social dynamics over time. This aligns with previous research suggesting that gamification designs that support intrinsic motivation—through autonomy, competence, and relatedness—tend to produce more meaningful and sustained engagement (Ryan and Deci, 2020; Sailer et al., 2017).

7.4 Alternative to Traditional Gamification Models

The findings also suggest a potential alternative to traditional cumulative gamification models that rely heavily on static leaderboards and reward systems. While leaderboards can be effective in motivating top-performing students, they often fail to address the needs of those who struggle early on, leading to disengagement and reduced participation over time (Hanus and Fox, 2015). The proposed framework offers a dynamic, iterative approach, where resets serve as "motivational checkpoints" that re-engage students and refresh competitive dynamics, creating a more inclusive environment for sustained participation and learning.

8. Conclusions

This study contributes to the growing body of research on gamification by demonstrating the potential of narrative-driven, iteratively reset competitive frameworks to sustain engagement and promote equity in higher education contexts. Grounded in self-determination theory, the design supports intrinsic motivation by fostering autonomy, competence, and relatedness. While further research is needed to refine and expand the framework, the findings suggest that such designs may offer a promising alternative to traditional gamification models, particularly in STEM education.

Key findings from the study reinforce these conclusions and provide answers to the research questions:

- RQ1: To what extent does narrative-driven competitive gamification influence student participation in optional learning activities? The gamified framework successfully motivated students to engage in tasks beyond the mandatory requirements, demonstrating its effectiveness in increasing voluntary participation.
- RQ2: What is the relationship between gamified engagement and academic performance? A strong positive relationship was observed between engagement and academic outcomes highlights the

importance of aligning gamification elements with learning objectives to support meaningful educational results.

- RQ3: How do repeated competitive cycles affect performance distribution? Periodic resets within competitive cycles sustained motivation across diverse performance levels, offering renewed opportunities for success and fostering greater equity in competitive environments.

These insights underscore the potential of structured, narrative-driven gamification frameworks to address common challenges in educational settings, such as performance disparities and disengagement.

9. Limitations and Future Directions

While the study provides valuable insights, several limitations must be acknowledged. First, the quasi-experimental design limits the ability to establish causal relationships between gamified engagement and academic outcomes. Second, the small sample size ($n = 56$) and context—an undergraduate IoT course—may restrict the generalizability of the findings to other disciplines or educational levels. Finally, the short duration prevents conclusions about long-term effects. Future research should explore the application of this framework in diverse contexts, such as the humanities or social sciences, and examine its long-term impact on academic performance through longitudinal studies.

Additionally, further investigation is needed to understand the interplay between narrative and competition in gamification design. For example, how do different types of narratives influence student engagement, and what role do social dynamics play in competitive environments? Addressing these questions could provide deeper insights into the mechanisms underlying effective gamification strategies.

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Ethics Declaration: Formal ethical clearance was not required for this study. The research relied on data derived from standard instructional activities rather than from surveys or direct elicitation methods. All data were processed in aggregated form, ensuring anonymity, and no personally identifiable information was collected or reported.

AI Declaration: Grammarly, an AI-powered writing assistant, was used during the preparation of this paper. The tool supported the revision process by identifying grammar, spelling, and punctuation issues and suggesting improvements for clarity and conciseness. All suggestions provided by the tool were carefully reviewed and selectively applied by the author to maintain the intended meaning and academic tone of the paper.

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