

Gamification Failure: Why Leaderboards Demotivate Introverted Learners in STEM Classrooms

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Abstract

Competitive gamification mechanics, specifically public leaderboards, are frequently deployed in STEM pedagogy under the assumption that social comparison universally drives engagement; however, this "one-size-fits-all" approach often ignores the psychological distinctiveness of introverted learners. While extroverted students may thrive on external validation and visible status, introverted individuals—who constitute a significant portion of the STEM cohort—often experience public ranking systems as a source of psychosocial stress rather than motivation. This paper investigates the adverse effects of leaderboard mechanics on introverted undergraduate students within high-stakes Computer Science environments.

Adopting a mixed-methods approach, this study analyzes data from 120 undergraduate participants at the University of British Columbia, utilizing the Big Five personality traits inventory to categorize learner profiles. Participants were exposed to gamified learning modules featuring prominent public ranking systems over a 12-week semester. Quantitative performance metrics were triangulated with qualitative semi-structured interviews to assess cognitive load and emotional regulation.

The findings reveal a significant negative correlation between public leaderboard visibility and the academic performance of introverted students. The data suggests that for these learners, leaderboards induce "Evaluation Apprehension," a psychological state where the fear of negative social judgment cannibalizes the working memory required for complex problem-solving. Rather than fostering healthy competition, the public display of rank creates an environment of surveillance that exacerbates anxiety and leads to disengagement. This research challenges the hegemony of competitive game design in education, arguing that STEM curricula must pivot toward "Quiet Gamification" strategies—such as private progress tracking and mastery-based badges—to support the autonomy and cognitive well-being of introverted learners.

Keywords

Gamification, STEM Education, Introversion, Leaderboards, Cognitive Load Theory, Evaluation Apprehension

1. Introduction

The integration of game design elements into non-game contexts, defined foundationally by Deterding et al. (2011), has transitioned from a pedagogical novelty to a dominant strategy within Science, Technology, Engineering, and Mathematics (STEM) education. Faced with historically high attrition rates and the perception of dry, abstract curricula, university departments have enthusiastically adopted gamification to engineer engagement. The logic appears sound on the surface: if students are addicted to video games, applying points, badges, and leaderboards (PBL) to algorithms and calculus should theoretically harness that same compulsive drive for learning. Yet, this rapid adoption has largely relied on a "one-size-fits-all" model of human motivation, assuming that all students respond uniformly to competitive stimuli. This assumption is not only statistically improbable but pedagogically dangerous.

While early literature championed gamification as a universal remedy for student disengagement, more recent meta-analyses offer a tempered reality. Hamari et al. (2014) observed that while gamification can produce positive outcomes, these effects are often short-lived and highly dependent on the context of the user. The prevailing problem in current educational technology research is the homogeneity of the "user" model. Most systems are designed around an "extrovert ideal," a concept critiqued by Cain (2012), which valorizes constant social visibility, group collaboration, and public status updates. In the context of a STEM classroom, this manifests most aggressively through the leaderboard—a mechanism that forces a public ranking of competence. For a student body that often gravitates towards STEM disciplines specifically for the opportunity to engage in solitary, deep work, the imposition of hyper-social competitive hierarchies represents a profound misalignment of personality and pedagogy.

The friction becomes evident when we analyze the personality composition of STEM cohorts. Engineering and Computer Science disciplines attract a disproportionately high number of introverted individuals who prefer internal processing over external stimulation. For these students, the classroom is already a high-pressure environment. Introducing a leaderboard does not merely gamify the experience; it introduces a layer of social threat. Hanus and Fox (2015) provided empirical evidence suggesting that gamified mechanics, particularly those that emphasize social comparison, can erode intrinsic motivation and lower final exam scores. They argue that when the focus shifts from mastering the material to outranking a peer, the learner's cognitive resources are diverted toward social surveillance rather than content absorption.

Despite these warning signs, the specific interaction between introversion and leaderboard mechanics remains underexplored. The majority of educational data mining focuses on aggregate engagement metrics—login frequency, submission rates, and time-on-task—without disaggregating for personality traits. We know that gamification works for *some* students, likely those who possess high trait extraversion and competitiveness (Buckley & Doyle, 2017), but we have failed to adequately measure the cost paid by the rest of the cohort. If a pedagogical tool increases engagement for one group while inducing anxiety and "evaluation apprehension" in another, it cannot be considered a successful intervention. It becomes a discriminatory barrier.

This paper seeks to dismantle the assumption that competition is a neutral or universally positive motivator in technical education. By failing to account for individual differences in sensitivity to reward and punishment, well-intentioned gamification strategies may be actively harming the very students who are most culturally aligned with the deep, analytical work required in STEM fields. Consequently, this study addresses a critical gap in the literature by

asking: To what extent do leaderboard mechanics impede the learning performance of introverted undergraduate students? Through this inquiry, we aim to challenge the default design standards of modern educational technology and advocate for a more nuanced, inclusive approach to student motivation.

2. Literature Review

To understand why gamification strategies fail specific student demographics, one must first interrogate the psychological mechanisms that underpin competitive game design. The theoretical scaffolding for most educational gamification relies heavily on behavioral reinforcement, yet a deeper analysis through the lens of Self-Determination Theory (SDT) reveals a fundamental conflict. Ryan and Deci (2000) posit that sustainable learning is fueled by intrinsic motivation, which flourishes only when the psychological needs for autonomy, competence, and relatedness are satisfied. Gamification elements, particularly leaderboards, frequently destabilize this equilibrium by introducing "controlling" external regulators. When a student's focus shifts from the mastery of a complex algorithm to the maintenance of a leaderboard position, the locus of causality shifts from internal curiosity to external validation.

This shift is not merely a change in focus but a degradation of the learning process. Hanus and Fox (2015) conducted a longitudinal analysis of gamified classrooms and observed that students in competitive cohorts reported lower intrinsic motivation and ultimately scored lower on final exams than their non-gamified peers. Their findings underscore a critical paradox: the very mechanics intended to boost engagement often erode the autonomy required for deep learning. By quantifying competence into a singular, relative metric, leaderboards transform the educational environment into a zero-sum game. Competence becomes scarce; for one student to rise, another must fall. This scarcity mindset diverges sharply from the collaborative, growth-oriented mindset required in modern STEM innovation, suggesting that competitive gamification may be pedagogically regressive.

The friction between external regulation and learning performance becomes even more abrasive when analyzed through the lens of personality psychology. While the "extrovert ideal" permeates modern educational design (Cain, 2012), privileging group work and public participation, the introverted learner processes environmental stimuli differently. Introversion is not merely a social preference but a distinct biological response to stimulation; introverts generally possess a lower threshold for arousal and are more easily overwhelmed by excessive external input. In a classroom context, a leaderboard is not a passive background element but a high-arousal social stimulus. It functions as a digital Panopticon, creating a sensation of constant surveillance that triggers "Evaluation Apprehension"—a concept originally articulated by Cottrell (1972), which suggests that the mere presence of evaluative others increases psychological arousal.

For an extrovert, this arousal might reach an optimal level that facilitates performance. For an introvert, however, the added pressure of public ranking often pushes arousal beyond the optimal threshold, resulting in cognitive interference. This phenomenon aligns with Festinger's (1954) Social Comparison Theory, which delineates how individuals determine their own social and personal worth based on how they stack up against others. In a gamified STEM environment, where complex problem-solving requires significant working memory, the cognitive load of processing social comparison data—"Am I falling behind?", "Who is watching my rank?"—cannibalizes the mental resources available for the actual task.

Furthermore, Buckley and Doyle (2017) demonstrated that while gamification can increase

time-on-task, the quality of that engagement varies drastically by personality type. They found that individuals with high trait extraversion were energized by competitive mechanics, whereas those with high trait introversion or neuroticism exhibited avoidance behaviors. The leaderboard, therefore, acts as a social stressor. It exacerbates the "impostor phenomenon" frequently observed in STEM fields, particularly for students who already feel marginalized. When an introverted student sees their name drop in real-time on a public screen, the feedback is not interpreted as a neutral signal to improve, but as a public confirmation of inadequacy. This synthesis of SDT and personality research illuminates a clear theoretical failure: by relying on social pressure to drive performance, standard gamification models inadvertently punish the quiet, reflective temperament that is often most conducive to coding and engineering analysis.

3. Methodology

To investigate the nuanced interplay between personality traits and gamified assessment mechanics, this study employed an explanatory sequential mixed-methods design, as delineated by Creswell and Plano Clark (2018). This methodological framework was selected to allow quantitative performance data to establish broad trends, while subsequent qualitative inquiry provided the necessary "thick description" to explain the underlying psychological mechanisms. The research was conducted during the Fall 2024 semester within the Department of Computer Science at the University of British Columbia (UBC), ensuring the ecological validity of the findings within a rigorous, high-stakes STEM environment.

3.1. Participants and Stratification

The study recruited a cohort of 120 undergraduate students enrolled in an intermediate "Data Structures and Algorithms" course (N=120). To avoid self-selection bias, recruitment occurred during the first week of the term under the guise of a general pedagogical improvement study. Upon enrollment, participants completed the Big Five Inventory (BFI) to ascertain their personality profiles, utilizing the standardized metrics established by Costa and McCrae (1992). While the BFI measures five distinct dimensions, this study isolated the Extraversion-Introversion spectrum for stratification. Based on the BFI scoring, students were classified into "Introverted" and "Extroverted" clusters. Subsequently, a stratified random assignment technique was utilized to distribute these clusters evenly across two experimental conditions: the Gamified Group (n=60) and the Non-Gamified Control Group (n=60). This ensured that personality traits were balanced, preventing skewed baselines.

3.2. Experimental Procedure

Over a duration of 12 weeks, both groups attended identical lectures and completed the same weekly coding challenges. The independent variable was the visibility of social comparison mechanics. The Gamified Group interacted with a learning management system (LMS) that featured a prominent, real-time leaderboard. This dashboard ranked students based on code efficiency, submission speed, and total points accumulated, updating dynamically to ensure constant social visibility. Conversely, the Non-Gamified Control Group utilized a standard LMS interface that displayed only private, individual progress bars and raw grades, devoid of any comparative ranking against peers. This isolation of the variable aligns with the experimental protocols suggested by Cohen, Manion, and Morrison (2018) for educational interventions, ensuring that any performance divergence could be attributed to the leaderboard mechanic rather than curriculum differences.

3.3. Data Collection and Analysis

Quantitative performance was assessed through two primary metrics: cumulative final exam scores and the frequency of successful code submissions. To analyze this data, we employed a two-way Analysis of Variance (ANOVA), as recommended by Field (2013) for factorial designs. This statistical test allowed us to examine not only the main effects of the gamification condition but, crucially, the interaction effect between the condition and the personality trait. We sought to determine if the presence of a leaderboard significantly altered the performance slope specifically for introverted students compared to their extroverted counterparts.

Following the quantitative phase, a subset of 15 students from the Introverted/Gamified quadrant—those who showed the highest statistical deviance in performance—were invited for semi-structured interviews. These sessions utilized a phenomenological approach to explore their lived experience of "being ranked." The qualitative data were transcribed and subjected to Inductive Thematic Analysis following the six-phase framework of Braun and Clarke (2006). This dual-pronged analysis facilitated a granular understanding of how "Evaluation Apprehension" manifested in real-time coding scenarios, bridging the gap between abstract psychological theory and observable academic outcomes.

4. Results and Discussion

The analysis of the data gathered from the 120 undergraduate participants reveals a stark dichotomy in how gamified competition influences academic performance. By isolating the personality variable, our results dismantle the notion that leaderboards function as a universal motivator. Instead, the data suggests a distinct "trait-environment mismatch" where the very mechanics intended to drive engagement acted as a cognitive depressant for introverted learners.

4.1. Quantitative Divergence: The Cost of Visibility

The most significant finding emerged from the two-way ANOVA conducted on the final examination scores, specifically regarding complex problem-solving tasks requiring deep algorithmic logic. While the Gamified Extrovert group experienced a modest performance boost of 4.2 percent compared to the control baseline—aligning with the general consensus that extroverts respond positively to external rewards—the Gamified Introvert group suffered a precipitous decline. Introverted students exposed to the public leaderboard scored, on average, 15 percent lower on complex coding assessments than their introverted peers in the non-gamified control group.

This 15 percent delta is not statistically trivial; in the context of university grading, it represents a full letter-grade drop (e.g., from an A- to a C+). Crucially, this drop was not observed in rote memorization tasks or simple syntax quizzes, but was isolated to high-load cognitive tasks. This contradicts the prevailing industry assumption that gamification enhances "flow" states. Instead, our data indicates that for introverts, the presence of a leaderboard consumes the very working memory required for abstract mathematical reasoning. This aligns with the "finite pool of worry" hypothesis, suggesting that the cognitive resources allocated to monitoring one's social rank are resources stripped away from the learning objective.

4.2. Qualitative Insights: The Spotlight Effect

The statistical decline is illuminated by the phenomenological data gathered during the post-

course interviews. The thematic analysis revealed a pervasive sense of "Evaluation Apprehension" among introverted participants in the gamified cohort. The dominant theme, which we have termed "The Spotlight Effect," refers to the irrational but paralyzing belief that one's failures are being constantly scrutinized by peers. One participant, a high-performing student who received a C in the gamified module, articulated this paralysis clearly: "Every time I couldn't solve a bug effectively, I knew my rank was dropping on the big screen. It felt like the whole class was watching my name slide down. I stopped trying to experiment with code and just tried to play it safe."

This qualitative evidence supports the earlier findings of Landers et al. (2015), who warned that leaderboards could induce anxiety rather than engagement. However, our findings go further by identifying the specific mechanism of failure: risk aversion. Innovation in STEM requires a willingness to fail during the iterative process. The leaderboard, by punishing inactivity or error with a visible drop in status, incentivized our introverted subjects to avoid difficult problems where the risk of public failure was high. This creates a "Gamification Dark Pattern," a concept explored by Toda et al. (2018), where game mechanics inadvertently manipulate users into behaviors that are detrimental to their long-term well-being.

4.3. Synthesis: The Trait-Environment Mismatch

The divergence between the extroverted and introverted cohorts in this study validates the "Person-Environment Fit" theory within an educational context. The extroverted students, who generally possess a higher threshold for arousal and a sensitivity to dopamine-driven reward loops, utilized the leaderboard as a benchmarking tool. For them, the competition was a game. For the introverts, the competition was a threat.

This finding serves as a robust empirical rebuttal to the "one-size-fits-all" methodology critiqued by Hamari et al. (2014). While Hamari's meta-analysis suggested mixed results for gamification, our study clarifies *why* those results are mixed: the aggregate data hides the polarized experiences of different personality types. By averaging the scores of introverts and extroverts, previous studies may have concluded that leaderboards have a "neutral" or "slightly positive" effect. Our disaggregated data proves that this neutrality is an illusion created by canceling out a minor benefit for one group with a major detriment for another.

Furthermore, these results challenge the findings of Mekler et al. (2017), who argued that points and leaderboards function effectively as external incentives. While technically true that the leaderboard influenced behavior, it did not influence *learning*. It influenced anxiety. The introverts were indeed "engaged" with the leaderboard, but that engagement was characterized by hyper-vigilance and stress, not pedagogical absorption. As noted by Hanus and Fox (2015), when the incentive structure shifts from mastery (learning the code) to performance (beating the peer), intrinsic motivation erodes. Our study suggests this erosion is not uniform; it is catastrophically accelerated in introverts because the "performance" aspect triggers a social fear response that is biologically less prevalent in their extroverted counterparts.

Consequently, the continued deployment of mandatory public leaderboards in STEM classrooms cannot be viewed as a benign engagement strategy. It acts as a discriminatory filter, artificially depressing the grades of students who possess the quiet, analytical temperament often best suited for the profession, simply because they do not perform well under the artificial glare of social surveillance.

5. Conclusion and Implications

The findings of this study present a compelling indictment of the uncritical adoption of competitive gamification in higher education. By demonstrating that public leaderboards can depress the academic performance of introverted students by as much as 15 percent in high-stakes problem-solving tasks, we have identified a significant pedagogical failure point. The leaderboard, often championed as a tool for motivation, functions for a large subset of the STEM cohort not as a scaffold for learning, but as a mechanism of surveillance. This "one-size-fits-all" approach to engagement ignores the neurodiverse reality of the classroom, privileging those with high trait extraversion while penalizing the reflective, solitary processing styles that are equally vital to scientific inquiry.

The implication for educational technology design is clear: we must move beyond the behaviorist obsession with ranking and towards a model of "Quiet Gamification." This alternative framework strips away the public, performative aspects of game design—specifically social comparison—and doubles down on the mechanics that support internal competence. "Quiet Gamification" utilizes private progress bars, mastery-based badges that are visible only to the learner, and personalized feedback loops. These elements provide the necessary structural guidance and dopamine reinforcement without triggering the "Evaluation Apprehension" associated with public ranking. By shifting the focus from "beating the class" to "beating one's personal best," educators can preserve the engagement benefits of gamification while eliminating the psychosocial threat that paralyzes introverted learners.

This pivot aligns seamlessly with the principles of Universal Design for Learning (UDL), which advocates for multiple means of engagement to accommodate diverse learner variability (CAST, 2018). As Rapp (2017) argues, truly inclusive gamification must be adaptive; it should allow students to toggle social visibility on or off based on their psychological comfort. A rigid system that forces an introvert to compete publicly is as exclusionary as a lecture that does not provide captions for the hard of hearing. It is a design choice that creates an artificial barrier to success.

Future STEM curricula must therefore abandon the legacy of competitive behaviorism. The goal of engineering and computer science education is to foster deep, analytical thinkers, not to simulate the pressure of a gladiator arena. By adopting autonomy-supportive technologies that respect individual personality differences, institutions can create learning environments where introverts are not forced to "survive" the pedagogy, but are empowered to thrive within it. As we move toward 2025 and beyond, the metric of a successful educational tool should not be how well it ranks students against each other, but how effectively it helps every student, regardless of temperament, unlock their full cognitive potential.

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