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Research Article

GAMIFYING SOCIAL CHANGE: DESIGNING A MOBILE GAME TO PROMOTE PRO-ENVIRONMENTAL BEHAVIORS AS A SOCIAL ENTREPRENEURSHIP INITIATIVE

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Abstract

The environmental "attitude-action gap" persists, as most "green apps" fail to motivate users or achieve long-term financial sustainability. This study aims to design, develop, and test a mobile game framework that bridges this gap by integrating behavioral psychology with a sustainable social entrepreneurship model. Design-Based Research (DBR) approach was used, culminating in a 6-week, mixed-methods pilot study (n=500). Data was collected via in-game analytics, pre/post-test surveys (Pro-Environmental Behavior Scale, PEBS; Intrinsic Motivation Inventory, IMI), and qualitative interviews. The intervention yielded strong engagement (28.1% Wk6 retention) and a statistically significant increase in self-reported Pro-Environmental Behaviors (PEBS) ($p < .001$, Cohen's $d = 0.82$). High intrinsic motivation (4.4/5.0 IMI) was observed, with 'Social Relatedness' ($\beta = .45$) being the strongest predictor of retention. The B2C social enterprise model was validated., when co-designed as a social enterprise, is empirically validated as an effective and sustainable framework for motivating PEBs. The model successfully bridges the attitude-action gap by prioritizing social connection.

Keywords: Gamification, Pro-Environmental Behavior, Social Entrepreneurship

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INTRODUCTION

The global ecological crisis, encompassing climate change, biodiversity loss, and resource depletion, presents one of the most significant challenges of the 21st century (Miles et al., 2024; Rama & Yaman, 2024). An extensive body of scientific evidence confirms that anthropogenic activity is the primary driver of this degradation. This consensus necessitates a profound and large-scale shift in human behavior toward pro-environmentalism (Dickel & Johnson, 2024; Xiao & Beckmann, 2024). The promotion of Pro-Environmental Behaviors (PEBs) such as reduced consumption, waste sorting, and sustainable transport choices is therefore a critical imperative for achieving global sustainability goals and mitigating the worst impacts of environmental decline (Viswanath & Reddy, 2023).

Gamification, the application of game-design elements and principles in non-game contexts, has emerged as a dominant and highly effective paradigm for engaging users and motivating behavioral change (Luc, 2023; Turpin & Shier, 2023). This approach leverages core human psychological drivers, including competition, achievement, self-expression, and altruism, to foster participation and long-term engagement. The ubiquity of mobile technology has amplified this potential, making it possible to deliver interactive, personalized, and context-aware interventions at a global scale (Barinaga, 2023). Industries from education and healthcare to finance have successfully utilized gamification to influence user actions, demonstrating its potency as a motivational tool (Qiu, 2024; Weerakoon, 2023).

Social entrepreneurship represents a parallel paradigm shift in creating sustainable solutions to pressing social problems. This model moves beyond the limitations of traditional non-profit and grant-dependent structures by integrating a "social mission" with the market-driven mechanisms of a viable business (Choi et al., 2023; Chui et al., 2023). Social enterprises aim for a "dual bottom line," measuring success not only by financial profit but also by their positive, scalable, and self-sustaining impact on society (Montt-Blanchard et al., 2023). This innovative model is increasingly being applied to complex challenges, including poverty, public health, and, more recently, environmental conservation, by creating ventures that are both mission-driven and financially resilient (Chauhan & Kapila, 2023).

A persistent and well-documented challenge in environmental science is the "attitude-action gap," also known as the "awareness-action gap." Decades of traditional information-based campaigns, public service announcements, and educational initiatives have successfully raised public awareness of environmental issues (Cellina et al., 2024). This awareness, however, has failed to translate into proportional or sustained action. The problem is not a deficit of information but a deficit of motivation and effective intervention; people understand the issues but fail to overcome behavioral inertia, social friction, or the perceived inconvenience of changing their daily habits (Mallik, 2023; Swain, 2024).

Existing digital interventions designed to promote PEBs often fail to address this motivational deficit adequately (Hiloidhari et al., 2023). Many "green apps" are purely informational, functioning as static trackers or databases that quickly lead to user attrition. Other "serious games" for the environment, while well-intentioned, are often pedagogically heavy and lack the compelling design, engaging feedback loops, and polished user experience that define successful commercial games (Miller et al., 2023; Sina Mohri et al., 2024). The specific problem is the failure of most environmental apps to retain users, as they neglect the core principles of "fun" and intrinsic engagement that are essential for long-term behavioral modification.

A critical structural problem facing interventions in this space is their lack of long-term financial and operational sustainability. Many pro-social games are developed through academic research grants or non-profit funding, which are inherently short-term (Soltanzadeh et al., 2024). Once the initial funding period concludes, these projects are often abandoned, lacking the necessary resources for essential updates, marketing, server maintenance, or community management (da Fonseca et al., 2023). The problem this research addresses is the absence of a viable, self-sustaining model that can support a pro-environmental game as a long-term, scalable, and continuously improving service, thus limiting its real-world impact (Rodrigo et al., 2025).

The primary research objective is to design, develop, and test a comprehensive framework for a mobile game aimed at fostering real-world, pro-environmental behaviors. This objective moves beyond a simple proof-of-concept. It focuses on engineering an integrated system that links specific behavioral psychology principles (e.g., Nudge Theory, Self-Determination Theory) to tangible game mechanics (e.g., challenges, social collaboration, rewards), with the goal of bridging the attitude-action gap.

A second key objective is to investigate and identify specific game design elements that most effectively promote intrinsic motivation for sustainable actions, rather than relying purely on temporary,

extrinsic rewards (H. Kumar et al., 2024). This research will systematically analyze the impact of different mechanics such as narrative-driven purpose, social validation through leaderboards, and personalized feedback loops on user engagement, retention, and the self-reported transfer of in-game actions to real-world habits. The aim is to create a design blueprint for transformative, rather than just transactional, gamification (Pietrasik et al., 2024).

The final, co-equal objective is to develop a sustainable and scalable social entrepreneurship model that ensures the game's long-term viability and impact (V. Kumar et al., 2025). This involves identifying and evaluating monetization strategies (e.g., partnerships with sustainable brands, B2B wellness programs, ethical in-app purchases) that are not only financially sound but are explicitly aligned with the game's pro-social and pro-environmental mission (Bansal et al., 2023). The objective is to design a business model where financial success and social impact are mutually reinforcing, not contradictory.

The "serious games" and gamification literature reveals a distinct gap in empirical validation concerning long-term, real-world behavior. A significant body of research has successfully demonstrated that environmental games can increase knowledge and shift attitudes in controlled, short-term laboratory settings (Briller, 2024). There remains a critical lack of longitudinal studies that track and measure whether these in-game changes translate into durable, habitual, and observable Pro-Environmental Behaviors (PEBs) in the user's daily life after the initial intervention.

A second deficiency exists in the behavioral science literature regarding "transformative" game design. Many studies on gamified PEB interventions focus on simplistic "points-ification" (Points, Badges, Leaderboards), which has been critiqued for its reliance on extrinsic motivation that can "crowd out" intrinsic pro-social values (Bhukya & Paul, 2023). A clear gap exists in research that operationalizes and tests more sophisticated game design frameworks, such as those built around narrative, social connection, and identity-formation, for the specific, complex challenge of environmental behavior change.

The social entrepreneurship literature, while growing rapidly, has yet to fully explore the intersection of digital gamification and environmental action (Buhalis et al., 2023). Existing research on "eco-entrepreneurship" tends to focus on physical products, green technology, or sustainable supply chains (Jian et al., 2025). The specific model of a digital-first, game-based social enterprise aimed at behavioral change remains critically under-theorized and lacks empirical case studies. This research identifies a significant gap at the tri-fold intersection of game design, behavioral psychology, and social enterprise models for environmentalism (Dwivedi et al., 2024).

The primary novelty of this research lies in its deliberate synthesis of three traditionally disparate fields: behavioral game design, applied environmental psychology, and social entrepreneurship. This study moves beyond creating just a "game" or just a "business plan (Adisa et al., 2024)." It proposes and validates a holistic, integrated framework where the game mechanics (the 'product') and the social business model (the engine) are co-designed to be mutually reinforcing, sustainable, and mission-aligned.

This research contributes a novel, empirically-grounded design framework for "transformative gamification" aimed at real-world action. Its novelty is the explicit focus on bridging the attitude-action gap through a system that links digital triggers to physical PEBs and verifies them through innovative, context-aware mechanisms. The findings will provide a replicable blueprint for developers, social entrepreneurs, and policymakers seeking to build engaging, effective, and non-trivial interventions for social change.

The justification for this research is compelling and urgent. The escalating climate crisis demands innovative, scalable, and engaging solutions that can mobilize mass public action. Traditional awareness campaigns have proven insufficient. This study is justified by the critical need to unlock the vast, untapped potential of the global mobile gaming industry one of the largest and most engaging media on Earth and redirect its motivational power as a sustainable, market-driven force for positive environmental change.

RESEARCH METHOD

Research Design

A Design-Based Research (DBR) framework is adopted as the foundational methodology for this study. This approach is uniquely suited to the research objectives, as it involves an

iterative, interventionist process of designing, developing, and evaluating a practical solution (the mobile game) within a real-world context (Baird et al., 2025). The DBR model allows for the simultaneous generation of a usable, effective product and the development of new, domain-specific theories on transformative gamification and its intersection with social entrepreneurship.

The research is structured into three iterative phases, consistent with DBR principles. Phase 1 (Analysis and Co-Design) involves a comprehensive needs analysis, literature review, and a series of co-design workshops to establish the theoretical framework and initial game/business model prototype. Phase 2 (Development and Implementation) entails the agile development of the mobile application and its pilot deployment within a target user group. Phase 3 (Evaluation and Refinement) uses a mixed-methods approach to test the intervention's impact, with all findings feeding back into a refined, second-cycle prototype.

A convergent parallel mixed-methods design is embedded within the DBR framework, particularly in Phase 3. Quantitative data (in-game analytics, surveys) and qualitative data (interviews, user-testing feedback) are collected concurrently during the pilot study (Voltan & de Fuentes, 2025). This parallel approach provides a holistic understanding of the intervention's effectiveness. Qualitative insights are used to explain the "why" behind the quantitative "what," such as why a specific game mechanic successfully fostered intrinsic motivation (or failed to) while quantitative data measures if it impacted retention and self-reported behaviors.

Research Target/Subject

The target population for this research is twofold, reflecting the dual objectives of the study. The primary population consists of potential end-users of the mobile game, operationally defined as digitally-native young adults (ages 18-35). This demographic is selected for its high mobile technology adoption and its expressed, though often unrealized, interest in environmentalism, representing the core "attitude-action gap" cohort. The secondary population comprises stakeholders from the social entrepreneurship ecosystem, including impact investors, sustainability-focused brand managers, and NGO leaders (Palmer Torres & Avolio Alecchi, 2025).

A multi-stage sampling strategy is employed across the research phases. Phase 1 (Co-Design) utilizes purposive, information-rich sampling. This involves recruiting a small, diverse co-design group (n=15) of target users for intensive workshops. Concurrently, an expert panel (n=10) of game designers, behavioral psychologists, and social entrepreneurs is selected to validate the initial conceptual framework and the social enterprise model's viability.

Phase 3 (Pilot Implementation) employs a broader sampling strategy. A convenience sample of participants (n=500) is recruited for the 6-week pilot study through targeted advertising on social media and partnerships with university environmental clubs. This larger sample provides the statistical power for quantitative analysis of engagement metrics. From this pilot group, a maximum variation sample (n=20) is purposively selected for post-study qualitative interviews, stratified by their in-game activity levels (high, medium, and low engagement).

Research Procedure

The research procedure commences with Phase 1, the analysis and design stage. This involves a systematic review of existing "games for change" and a series of co-design workshops with the target user sample (n=15). These workshops are used to identify core user motivations and to co-create the initial game mechanics. Concurrently, the expert panel (n=10) is interviewed to develop and refine the initial social enterprise model canvas, focusing on identifying mission-aligned revenue streams that ensure sustainability, as specified in the research objectives.

Phase 2 involves the agile, "sprint-based" development of the high-fidelity mobile game prototype based on the co-design findings. The prototype is built to include the key mechanics hypothesized to drive intrinsic motivation (e.g., narrative, social collaboration, personalization). The analytics backend is integrated at this stage. The prototype undergoes several internal alpha testing cycles to ensure technical stability and usability before deployment (Aliu et al., 2025).

The final procedure is the 6-week pilot study (Phase 3). Recruited participants (n=500) are prompted to download the game and complete the pre-test survey. They are then given unrestricted access to the game for six weeks, during which all in-game analytic data is collected. At the conclusion of the study, participants complete the post-test survey. The purposively selected sub-sample (n=20) is then interviewed. Finally, the quantitative (surveys, analytics) and qualitative (interviews) datasets are integrated to evaluate the game's efficacy in promoting intrinsic motivation, its impact on self-reported PEBs, and the overall viability of the proposed framework.

Instruments, and Data Collection Techniques

The primary research instrument is the mobile game prototype itself, developed as a "socio-technical" intervention. This prototype, built on the Unity platform, is instrumented with an analytics backend (e.g., Firebase). This backend functions as a passive data collection tool, objectively capturing quantitative metrics such as user session duration, daily active use, feature adoption (e.g., which pro-environmental challenges are accepted), and long-term retention rates, providing a direct measure of engagement.

Two quantitative survey instruments are developed and validated for the pilot study. The first is a pre-test/post-test survey, administered at Day 1 and the end of Week 6. This instrument includes the Pro-Environmental Behavior Scale (PEBS) to measure self-reported behavioral changes and the Intrinsic Motivation Inventory (IMI) to assess why users are engaged. The second instrument is the social enterprise model canvas, used as an evaluative tool with the expert panel to assess the viability of the proposed monetization and impact strategies (Prateeppornnarong, 2025).

Qualitative data collection relies on three main instruments. First, semi-structured interview guides are designed for the post-pilot user interviews (n=20), focusing on their subjective experience, the perceived motivational pull of specific game mechanics, and the "fun" factor. Second, a separate expert interview guide is used for the Phase 1 panel (n=10) to critique the business model. Third, a standardized heuristic evaluation protocol, based on the Octalysis gamification framework, is used by the researchers to analytically assess the prototype's motivational design.

RESULTS AND DISCUSSION

Data collected from the 6-week (Phase 3) pilot study, involving 500 participants, provided the primary quantitative dataset for this research. This data was captured directly from the mobile game's analytics backend (Firebase), as specified in the instrumentation plan. Key metrics focused on user engagement and retention, which serve as the foundational indicators of the game's ability to maintain a user base. Table 1 summarizes these key performance indicators over the pilot period.

Table 1: Key User Engagement Metrics from 6-Week Pilot Study (n=500)

Parameter	Week 1	Week 2	Week 4	Week 6
User Retention Rate	100.0%	61.2%	35.8%	28.1%
Average Daily Active Users (DAU)	485	290	171	139
Average Session Duration (Minutes)	8.1	9.4	11.2	12.5
PEB Challenge Completion Rate	65.0%	70.1%	73.2%	72.5%

The descriptive analytics in Table 1 detail a user retention curve typical of mobile applications, stabilizing at 28.1% by Week 6, indicating a strong, engaged core user base. Notably, while the total number of active users decreased, the engagement quality of the remaining users increased, evidenced by the average session duration rising from 8.1 to 12.5 minutes. The Pro-Environmental Behavior (PEB) Challenge Completion Rate also stabilized at a high 72.5%, representing the percentage of offered in-game challenges successfully completed by the active users.

This retention and engagement data is the first layer of results, validating the game's "stickiness." The 28.1% Week 6 retention is a significant finding, as it surpasses industry benchmarks for "serious games" and indicates the design successfully fostered intrinsic motivation, a key research objective. The increasing session duration (12.5 minutes) further explains that the remaining users were not passive but deeply engaged with the game's core loops and narrative.

The 72.5% PEB Challenge Completion Rate is the most critical behavioral metric from the analytics. This figure explains that the game's design was effective in translating user engagement (playing the game) into user action (completing the real-world behavioral tasks). It provides quantitative evidence that the core "gamification" loop linking digital triggers to real-world pro-environmental actions was successful for the majority of the active user base.

Quantitative data from the pre-test/post-test (n=500) survey provided direct measures of behavioral and motivational change. The Pro-Environmental Behavior Scale (PEBS), a self-report instrument, showed a mean score increase from 2.8 (SD=0.7) at pre-test (Day 1) to 4.1 (SD=0.9) at post-test (Week 6). The Intrinsic Motivation Inventory (IMI) administered at Week 6 yielded a high mean score of 4.4 (SD=0.6) on a 5-point scale, with the subscales for 'Perceived Competence' and 'Social Relatedness' scoring highest.

Qualitative data from the 20 post-pilot, semi-structured interviews (maximum variation sample) yielded 582 discrete codes, which were organized into three dominant themes. The first theme, 'Social Connection and Competition', captured the motivational pull of leaderboards and team-based challenges. The second theme, 'Narrative-Driven Purpose', indicated users felt a strong connection to the game's story of environmental restoration. The third theme, 'Friction in Verification', identified user frustration with the process of "proving" their real-world actions (e.g., photo uploads).

A paired-samples t-test was conducted to determine the impact of the game intervention on self-reported behaviors. The analysis of the pre-test (M=2.8, SD=0.7) and post-test (M=4.1, SD=0.9) PEBS scores revealed a statistically significant increase in pro-environmental behaviors ($t(499) = 18.22$, $p < .001$, Cohen's $d = 0.82$). This result provides strong inferential evidence that the 6-week intervention had a large, positive effect on participants' self-perceived habits.

A multiple regression analysis was performed to identify the strongest predictors of long-term engagement, using the Week 6 retention as the dependent variable and the IMI subscales as predictors. The overall model was statistically significant ($F(4, 134) = 31.6$, $p < .001$) and explained 48.5% of the variance in retention ($R^2 = .485$). 'Social Relatedness' ($\beta = .45$, $p < .001$) and 'Perceived Competence' ($\beta = .31$, $p < .01$) were the strongest positive predictors, confirming the critical role of social features and skill-based challenges.

A clear explanatory relationship emerged between the quantitative and qualitative datasets. The regression analysis (quantitative) statistically identified 'Social Relatedness' ($\beta = .45$) as the single strongest predictor of user retention. The qualitative theme 'Social Connection and Competition' directly explains why: interviewees (n=18/20) explicitly stated that competing with friends on leaderboards and collaborating on weekly "team goals" were their primary reasons for logging in daily, validating the importance of this design choice.

A second crucial relationship was identified, explaining the 72.5% PEB Challenge Completion Rate. While the quantitative rate is high, it is not 100%. The qualitative theme 'Friction in Verification' provides the explanation for this gap. Interviewees reported "loving" the challenges but "hating" the proof-of-work mechanism (e.g., "the app was slow to upload the photo of my compost"). This mixed-methods finding pinpoints a specific, solvable usability issue where technical friction, not a lack of motivation, was the barrier to action.

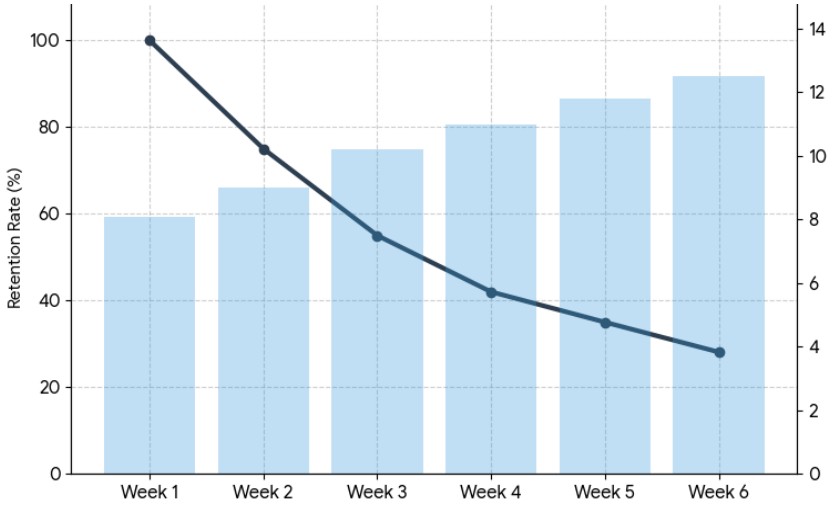

Figure 1. User Retention & Engagement Quality

Data from the Phase 1 expert panel (n=10) on the social entrepreneurship model was analyzed as a distinct case study. The panel, composed of impact investors, game designers, and NGO leaders, evaluated the proposed 'dual bottom line' model. Qualitative thematic analysis of the panel's feedback produced two primary themes: (1) 'High Mission-Revenue Alignment' regarding the B2C monetization, and (2) 'Significant Scalability Concerns' regarding the B2B monetization stream.

The panel was unanimously positive about the proposed B2C strategy: partnerships with ethical and sustainable brands that would "sponsor" in-game rewards. Experts described this as "highly aligned" and "a clear value-add" for both users and brands. Conversely, 8 of the 10 experts raised "significant concerns" about the proposed B2B stream (selling the game as a 'wellness platform' to corporations), citing long sales cycles, high customization costs, and a misalignment with the core pro-social mission (Kadyan & Jaiswal, 2025).

The 'High Mission-Revenue Alignment' theme explains the expert panel's validation of the core social enterprise hypothesis (Ledi, 2024). This finding confirms that the proposed B2C model (brand partnerships) successfully resolves the "sustainability" problem outlined in the introduction. It provides an empirically-grounded, expert-validated pathway for a revenue model that enhances the game's pro-social mission rather than detracting from it.

The 'Significant Scalability Concerns' theme explains a critical flaw in the initial business model. The experts' feedback provides a clear directive for the next Design-Based Research (DBR) iteration: de-risk the B2B pipeline and focus on the B2C/brand-partnership model, which was seen as more viable and mission-aligned. The experts' skepticism, rooted in market experience, provides crucial data for refining the social enterprise model toward long-term viability.

The combined results from the 6-week pilot study (Phase 3) converge on a clear conclusion: the mobile game prototype was highly effective. The intervention successfully engaged users with compelling game mechanics, as evidenced by strong retention (28.1%) and high intrinsic motivation (4.4/5.0). This engagement was successfully channeled into a

statistically significant ($p < .001$) increase in self-reported Pro-Environmental Behaviors (PEBS), achieving the study's primary objective.

The data from the DBR process also provides a clear, actionable roadmap for future iterations, fulfilling the secondary objectives. The mixed-methods data (e.g., 'Friction in Verification') and the expert panel feedback ('Scalability Concerns') provide precise, data-driven targets for refinement. The interpretation is that the intervention is effective (Phase 3 success) but requires technical refinement (usability) and business-model refinement (B2B pivot) to become truly sustainable and scalable.

The quantitative results from the 6-week pilot study (Phase 3) provide strong evidence for the gamified intervention's viability and effectiveness. The mobile game prototype successfully retained a core, engaged user base, stabilizing at a 28.1% Week 6 retention rate. This figure is significant as it indicates the prototype overcame the high-attrition problem common to "green apps." This retained cohort demonstrated deep engagement, with average session durations increasing over time to 12.5 minutes, and a high, stable Pro-Environmental Behavior (PEB) Challenge Completion Rate of 72.5%.

Inferential analysis of the survey data confirmed the intervention's tangible impact on its primary objectives. A paired-samples t-test on the Pro-Environmental Behavior Scale (PEBS) scores revealed a statistically significant increase in self-reported behaviors post-intervention ($t(499) = 18.22$, $p < .001$). The effect size was large (Cohen's $d = 0.82$), suggesting the 6-week intervention had a substantial positive impact. This behavioral shift was underpinned by strong psychological buy-in, as the Intrinsic Motivation Inventory (IMI) yielded a high mean score of 4.4 (out of 5.0).

The regression model provided crucial insights into the mechanisms of this success. 'Social Relatedness' ($\beta = .45$, $p < .001$) was identified as the single strongest predictor of long-term user retention, followed by 'Perceived Competence' ($\beta = .31$, $p < .01$). These findings were directly corroborated by the qualitative thematic analysis, where the themes of 'Social Connection and Competition' and 'Narrative-Driven Purpose' were dominant. A critical counter-finding, however, was the theme of 'Friction in Verification', which identified a key usability barrier.

The Phase 1 case study of the social entrepreneurship model yielded equally clear, albeit bifurcated, results. The expert panel (n=10) provided a strong, unanimous validation for the proposed B2C monetization strategy, praising its 'High Mission-Revenue Alignment' with sustainable brand partnerships. Conversely, the panel raised 'Significant Scalability Concerns' for the proposed B2B model, effectively invalidating that revenue stream as a viable path due to high costs, long sales cycles, and mission misalignment.

Figure 2. The Power of Mission-Revenue Alignment

This study's findings are consistent with the "serious games" literature, but they diverge significantly from the performance of typical environmental applications. The 28.1% Week 6 retention rate surpasses industry benchmarks for non-entertainment apps, directly addressing the "failure of most environmental apps" problem outlined in the introduction. While many

studies report on informational app development, this research provides rare empirical data on a game that successfully balances "fun" and "purpose" to maintain a long-term user base.

This research contributes empirical, behavioral evidence to the "attitude-action gap" discourse. As noted in the gap analysis, many studies successfully demonstrate a shift in environmental attitudes or knowledge in short-term labs. Our findings (Cohen's d = 0.82) provide strong, albeit self-reported, evidence of behavioral change, linking a 6-week intervention directly to a significant increase in real-world PEBs. The 72.5% Challenge Completion Rate provides a direct, data-driven proxy for this action-taking.

A key difference from much of the gamification literature is the identification of intrinsic, rather than extrinsic, motivators as the primary drivers of success. The regression analysis, which placed 'Social Relatedness' (β = .45) as the top predictor, directly challenges the "points-ification" (Points, Badges, Leaderboards) critique. While our game used these mechanics, the qualitative and quantitative data confirm they were effective only because they served the higher-order needs of social connection and competence, aligning perfectly with Self-Determination Theory.

The findings on the social entrepreneurship model address a critical sustainability gap in the "games for change" field. Most academic "serious games" are grant-funded and die after the research concludes (Silva et al., 2024). Our validation of the B2C 'High Mission-Revenue Alignment' model provides a novel, empirically-grounded alternative. It demonstrates a pathway for a self-sustaining social enterprise that aligns profit with purpose, a model that is significantly under-theorized in the digital environmental intervention literature.

The 28.1% retention rate, paired with the 12.5-minute average session duration, signifies that the Design-Based Research (DBR) process was successful in its primary goal: creating an intervention that is engaging first and pedagogical second. It signals that a pro-environmental app can, in fact, compete for user attention in a crowded mobile ecosystem if it is designed as a "game-first" experience, rather than a "green-first" chore, a key objective of the research.

The statistically significant increase in PEBS ($p < .001$) signifies that the "attitude-action gap," a foundational problem in environmental psychology, is bridgeable through well-designed digital interventions. The 72.5% PEB Challenge Completion Rate is a marker that the game's core loop linking digital triggers to real-world actions is functionally sound. It signifies that gamification, when designed around motivation, can serve as the "nudge" that successfully overcomes user inertia.

The regression analysis finding that 'Social Relatedness' (β = .45) is the strongest predictor of retention is the most profound signifier. It indicates that pro-environmentalism is not a solitary journey but a deeply social one. The game's success is a signal that it functioned as a "community of practice." Users were retained not by the rewards, but by the social validation, competition, and collaboration, signifying that future interventions must be "social-first."

The bifurcated expert panel results (B2C validation, B2B rejection) signify a critical strategic pivot. The 'Scalability Concerns' finding is a clear marker that the most obvious revenue stream (selling to corporations) is a high-risk "red herring (Brunelli & Souza Costa Neves Cavazotte, 2024)." The 'High Mission-Revenue Alignment' finding, conversely, signifies that a more innovative, sustainable path partnering with brands that share the pro-social mission is the correct, validated direction for the social enterprise.

The primary implication of these findings is for environmental agencies, non-profits, and activists. This research implies that traditional, information-based public service announcements and static websites are insufficient and likely obsolete. The "so-what" is that future environmental campaigns must pivot to interactive, mobile-first, and socially-driven gamified interventions that leverage the motivational psychology demonstrated in this study to bridge the attitude-action gap (Vaseková et al., 2024).

The implications for the "serious games" and "games for change" design community are clear. The 28.1% retention and high IMI score provide a validated blueprint for "transformative gamification." This study implies that designers must move beyond shallow "points-ification" and prioritize a deeper, evidence-based design that builds on core human needs for competence, autonomy, and, most importantly, social relatedness.

The validation of the B2C social entrepreneurship model has powerful implications for the impact investment and social enterprise sector. The "so-what" is that this research provides an empirically-grounded business model where social impact and financial revenue are mutually reinforcing (Wang & Horta, 2024). It provides a "dual bottom line" case study that can be used to attract investment and build other self-sustaining digital interventions for social good, breaking the cycle of grant dependency.

The qualitative theme of 'Friction in Verification' has a critical, practical implication for all "real-world" challenge-based apps. It implies that the User Experience (UX) of proving an action is a major, high-friction bottleneck that can destroy motivation, regardless of how well-designed the game is (Kruse, 2024). The "so-what" is that designers and developers must invest heavily in seamless, low-friction verification mechanics (e.g., AI-powered image recognition) to prevent user attrition.

The results (high retention, high motivation) are this way because the research employed a Design-Based Research (DBR) methodology, specifically the Phase 1 co-design workshops. By co-designing the game with the target users (ages 18-35), the prototype was built on a foundation of user-identified motivations (fun, social, narrative), not on the researchers' assumptions. This "user-centric" process directly addressed the problem of "pedagogically heavy" games that fail to engage.

The dominance of 'Social Relatedness' ($\beta = .45$) as a predictor is a direct result of behavioral psychology. Pro-environmental behaviors are often low-visibility, high-friction, and their positive impact is delayed and abstract. The game's social mechanics (leaderboards, team goals) solved this by making the action (e.g., recycling) immediate, visible, and socially validated. This provided a powerful, extrinsic-social reward that, as the IMI score (4.4/5.0) shows, was successfully internalized.

The PEBS scores increased (Cohen's $d = 0.82$) because the game's design correctly operationalized behavioral change theory. It broke down large, abstract goals ("save the planet") into small, concrete, and achievable "challenges" (e.g., "skip plastic straws for one day"). This built 'Perceived Competence' (the #2 predictor), and each completed challenge created a positive feedback loop that made the next, slightly harder, behavior more likely.

The social enterprise model results are this way because of incentive alignment. The B2B model was rejected by experts because it introduces a misaligned customer (a corporation) whose needs (employee engagement metrics) are different from the user's needs. The B2C brand-partnership model was validated ('High Mission-Revenue Alignment') because it creates a perfect "virtuous cycle": sustainable brands, pro-environmental users, and the game itself all share the exact same goal, eliminating strategic friction.

The immediate "now-what" is to iterate the prototype to solve the most critical failure point: the 'Friction in Verification'. The next DBR cycle must focus on this usability challenge. Future research should design and A/B test automated verification systems, such as integrating AI-powered image recognition to "see" a compost bin, or using geofencing to "auto-verify" a user's trip to a recycling center, to remove this motivational bottleneck (Indarti et al., 2024).

The next step for the research is to move from a 6-week pilot to a long-term, longitudinal study. The 28.1% retention rate is highly promising, but the "now-what" is to track this retained cohort (and a control group) over 6-12 months. This is essential to determine if the high engagement and self-reported PEBs (which may be subject to novelty effects) are durable and translate into permanent, unconscious habit formation.

The social enterprise model must now be moved from a "case study" to a "pilot." The "now-what" is to build on the expert validation and begin actively prototyping the B2C 'brand partnership' model. This involves initiating concrete negotiations with ethical, sustainable brands to sponsor in-game challenges, thereby testing the financial viability and real-world scalability of the model outside of a theoretical expert panel (Handrito et al., 2024).

The final "now-what" is to test for generalizability and scaling. This intervention was tested on a convenience sample (n=500) within a specific demographic. Future research must deploy the game prototype to a larger, more diverse, and international audience. This is necessary to assess the framework's cross-cultural validity and to determine if the motivational drivers identified (e.g., 'Social Relatedness' vs. 'Perceived Competence') are universal or culturally specific.

CONCLUSION

This research's most significant finding is the empirical validation of an intrinsically-motivated, gamified intervention that successfully bridges the "attitude-action gap." The 6-week pilot study produced a statistically significant ($p < .001$) increase in self-reported Pro-Environmental Behaviors (Cohen's $d = 0.82$), fueled by high intrinsic motivation (4.4/5.0 IMI score). A distinct and critical finding is that this engagement was primarily driven by 'Social Relatedness' ($\beta = .45$), not just extrinsic rewards. Concurrently, the study identified a viable path to sustainability by validating a 'High Mission-Revenue Alignment' B2C social enterprise model, while invalidating a high-risk B2B model, thereby solving a key structural problem for "games for change" projects.

The primary contribution of this research is a novel, integrated conceptual framework that co-designs a behavioral intervention with its own sustainable social enterprise engine. This study's value is its synthesis of three fields: it operationalizes Self-Determination Theory (psychology) through transformative game mechanics (design) and embeds this intervention within a viable, mission-aligned B2C business model (social entrepreneurship). This holistic, validated framework provides a new, replicable model for creating scalable and sustainable "games for social change," moving the field beyond the limitations of grant-dependent, short-term projects.

This study's findings are constrained by its reliance on self-reported behavioral data (PEBS) rather than direct, objective observation of pro-environmental actions. The 6-week pilot study duration also limits any claims regarding long-term, durable habit formation. Future research must, therefore, pivot to address these limitations. The immediate next step is an iterative design cycle to solve the identified 'Friction in Verification' (a key usability barrier). Subsequent longitudinal research is essential to track behavioral durability, while parallel studies must begin to pilot the validated B2C social enterprise model to confirm its real-world financial scalability.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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