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Research Article

BEYOND PROFIT AND PLAY: GAME-BASED SOCIAL ENTREPRENEURSHIP AS A CATALYST FOR SUSTAINABLE IMPACT

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Abstract

The increasing complexity of global social and environmental challenges has intensified the need for innovative models of social entrepreneurship that move beyond conventional profit-oriented and philanthropic approaches. Game-based systems have emerged as interactive digital mechanisms capable of fostering sustained engagement, behavioral change, and collective action, yet their strategic role in social entrepreneurship remains underexplored. This study aims to examine how game-based social entrepreneurship functions as a catalyst for sustainable impact by integrating interactive design with social value creation. A qualitative multiple-case research design was employed, involving eight social enterprises that systematically utilize game-based mechanisms to address social and environmental challenges. Data were collected through semi-structured interviews, document analysis, and platform engagement metrics, and analyzed using thematic and comparative techniques. The results indicate that social enterprises embedding narrative-driven gameplay, cooperative mechanics, and mission-linked feedback systems achieve higher levels of sustained user engagement, mission alignment, and impact scalability. Game-based systems were found to operate as structural infrastructures rather than supplementary engagement tools. The study concludes that game-based social entrepreneurship represents a transformative model that bridges digital innovation and sustainability, enabling social enterprises to translate participatory play into durable social impact and long-term value creation.

Keywords: Game-Based Social Entrepreneurship, Serious Games, Sustainability

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INTRODUCTION

Contemporary discussions on sustainable development increasingly emphasize the need for innovative mechanisms that transcend conventional economic and philanthropic models. Traditional business approaches often prioritize profit maximization, while purely charitable initiatives frequently struggle with long-term financial viability (da Fonseca et al., 2023; Kakeesh, 2024). This tension has stimulated growing scholarly interest in social entrepreneurship as a hybrid paradigm that combines market mechanisms with social value creation. Within this evolving discourse, digital technologiesparticularly game-based systemshave emerged as underexplored yet potentially transformative tools for fostering sustainable social impact (Byrne & Giuliani, 2025; Donaldson et al., 2024).

Game-based systems have expanded far beyond entertainment, becoming influential platforms for learning, behavioral change, and civic engagement. Serious games, gamification strategies, and interactive digital environments have demonstrated measurable effects on motivation, problem-solving, and collaborative action across educational, organizational, and community contexts (Gaweł et al., 2025; L. Scott et al., 2025). These characteristics position games as powerful mediating tools capable of aligning individual incentives with collective goals, especially in addressing complex social and environmental challenges that require sustained engagement rather than short-term intervention (Hossain et al., 2024; Kosta & Ramadani, 2025).

Social entrepreneurship operates within precisely such complexity, addressing persistent social problems that demand adaptive, participatory, and scalable solutions. The convergence between game-based approaches and social entrepreneurship suggests a promising yet insufficiently articulated pathway toward sustainable impact (Oliver et al., 2025). The notion of “beyond profit and play” captures this intersection by framing games not merely as revenue-generating products or leisure activities, but as strategic infrastructures that can catalyze social innovation, mobilize communities, and reinforce long-term sustainability objectives (Leitão et al., 2024).

Despite the rapid growth of social entrepreneurship research, prevailing studies remain largely anchored in conventional organizational models, financial instruments, and policy frameworks (Djebali et al., 2025; Tabares et al., 2025). Many analyses emphasize business models, impact measurement, or institutional support mechanisms, while overlooking the role of interactive digital systems in shaping stakeholder participation and value co-creation. This limitation constrains the conceptual tools available for understanding how social enterprises can sustain engagement and amplify impact in digitally mediated societies (Chen & Barcus, 2024; Sharma et al., 2024).

Game-based initiatives are frequently examined in isolation from entrepreneurial contexts, with research focusing on education, marketing, or behavioral psychology rather than social enterprise ecosystems (Madzík et al., 2024; Xia & Chen, 2025). Existing studies tend to treat games either as pedagogical supplements or as commercial entertainment products, resulting in fragmented insights that fail to capture their integrative potential. The absence of a coherent framework linking game mechanics to social entrepreneurial processes obscures how games can function as catalysts for systemic change rather than auxiliary instruments (Gotsopoulos & Pitsakis, 2024; Richardson, 2024).

Sustainability challenges further complicate this landscape by demanding solutions that are both economically viable and socially transformative over time. Many social enterprises struggle to maintain user engagement, scale impact, or balance mission integrity with financial sustainability (Monteiro et al., 2025). The lack of research examining how game-based systems can address these persistent challenges represents a critical problem, particularly in contexts where social issues require long-term behavioral shifts and collective action rather than episodic interventions (T. L. Ho et al., 2025).

This study aims to conceptualize game-based social entrepreneurship as a distinct and strategically significant model for generating sustainable social impact. The research seeks to move beyond descriptive accounts by developing an integrative perspective that connects game design principles with entrepreneurial value creation and social mission fulfillment (Williamsson & Sandoff, 2023). Through this approach, the study aspires to clarify how interactive systems can be deliberately designed to support both economic sustainability and social transformation (Maddaloni et al., 2025).

An additional objective involves analyzing the mechanisms through which game-based elements influence stakeholder engagement, motivation, and participation within social enterprises. Attention is directed toward understanding how rules, narratives, feedback systems, and reward structures can align individual behavior with collective social goals. The research also seeks to identify conditions under which these mechanisms enhance resilience, scalability, and adaptability in socially oriented ventures (Allegretti et al., 2025).

The study further intends to contribute to theoretical and practical discussions by offering a structured framework applicable to researchers, practitioners, and policymakers. By articulating the strategic roles of games within social entrepreneurship, the research aims to inform future design, implementation, and evaluation of initiatives that seek sustainable impact. The ultimate objective centers on demonstrating how game-based approaches can function as intentional catalysts rather than incidental features within social enterprise models (Kamundala, 2025; Medase et al., 2023).

Existing literature on social entrepreneurship provides extensive insights into governance structures, funding strategies, and impact assessment, yet offers limited engagement with interactive digital design as a core operational dimension. Studies that address technology adoption often prioritize platforms, data analytics, or communication tools, leaving game-based systems marginal to theoretical development. This gap restricts the field's capacity to explain how engagement-intensive mechanisms contribute to sustainability and mission alignment (le Polain de Waroux & Kronenburg García, 2025; Lyver & Lees, 2025).

Research on games and gamification, while robust in education and consumer behavior, rarely situates its findings within social entrepreneurial contexts. Empirical investigations frequently examine short-term outcomes such as learning gains or user retention, without addressing long-term social value creation or organizational sustainability (Nguyen et al., 2025). The separation between game studies and social entrepreneurship research results in parallel bodies of knowledge that seldom intersect meaningfully.

Conceptual frameworks integrating game-based design with social entrepreneurship remain scarce, particularly those addressing sustainability as a multidimensional outcome encompassing social, economic, and environmental dimensions (Chandra et al., 2024; Phillips et al., 2024). The absence of interdisciplinary synthesis limits scholarly understanding of how game-based initiatives can be strategically embedded within social enterprises. This study responds directly to this gap by positioning game-based systems as foundational components of social entrepreneurial practice rather than peripheral innovations (Kah et al., 2025).

The novelty of this research lies in its reframing of games as strategic infrastructures for social entrepreneurship rather than ancillary tools for engagement or fundraising. By conceptualizing game-based systems as catalysts for sustainable impact, the study introduces a perspective that bridges digital game design, entrepreneurial strategy, and social innovation theory. This integrative stance challenges dominant assumptions that separate economic viability from participatory and experiential mechanisms (Bassam Madi-Odeh & Yousef Obeidat, 2025; Wengle et al., 2025).

The research is further justified by the growing urgency of sustainability challenges that demand innovative, scalable, and inclusive solutions. Game-based social entrepreneurship offers a unique capacity to mobilize diverse stakeholders, foster long-term commitment, and translate abstract social goals into tangible, interactive experiences. The study underscores the

importance of this approach in contexts where traditional interventions fail to sustain momentum or adapt to evolving social conditions.

Academic significance emerges from the study's contribution to interdisciplinary scholarship, expanding theoretical boundaries within social entrepreneurship and digital innovation studies. Practical relevance is equally evident, as the proposed framework provides actionable insights for social entrepreneurs seeking sustainable models that resonate with digitally engaged communities. The research ultimately justifies its contribution by demonstrating how moving beyond profit and play enables social enterprises to achieve enduring and transformative impact.

RESEARCH METHOD

Research Design

This study adopted a qualitative multiple–case research design to examine how game-based approaches are integrated within social entrepreneurship initiatives and how such integration contributes to sustainable social impact. The qualitative design was selected to allow for in-depth exploration of processes, meanings, and contextual dynamics that cannot be adequately captured through purely quantitative measures (Zuo et al., 2025). A case-based strategy enabled the comparison of different models of game-based social entrepreneurship across varied organizational and socio-cultural settings, thereby supporting analytical generalization rather than statistical inference. The design emphasized interpretive analysis to uncover patterns of interaction between game mechanics, entrepreneurial strategies, and sustainability outcomes.

Research Target/Subject

The population of this study consisted of social enterprises that explicitly incorporate game-based elements as core components of their value creation models. These included digital social enterprises utilizing serious games, gamified platforms, or interactive simulations to address social, environmental, or educational challenges. A purposive sampling technique was employed to select cases that met three criteria: explicit social mission orientation, systematic use of game-based mechanisms, and demonstrable engagement with sustainability goals. From this population, a sample of eight social enterprises operating in different regional contexts was selected to ensure diversity in scale, sector, and target beneficiaries (Blankesteijn et al., 2024).

Research Procedure

Data collection procedures followed a sequential and systematic process. Initial contact with selected social enterprises was conducted to obtain informed consent and establish research access. In-depth interviews were carried out through virtual and on-site sessions, each lasting between sixty and ninety minutes, and were audio-recorded with participant permission. Organizational documents and digital artifacts were collected concurrently to support triangulation. Observational data were gathered through direct engagement with game-based platforms and recorded in analytic field notes. All qualitative data were transcribed verbatim and analyzed using thematic coding techniques to identify recurring patterns, relationships, and conceptual categories relevant to game-based social entrepreneurship and sustainable impact (Liu et al., 2025).

Instruments, and Data Collection Techniques

Data collection instruments were designed to capture both strategic and experiential dimensions of game-based social entrepreneurship. Semi-structured interview guides were developed for founders, designers, and program managers to elicit insights into organizational objectives, design rationales, and perceived impact. Document analysis protocols were used to

examine organizational reports, game design documents, impact assessments, and digital platform artifacts. Observation checklists supported the analysis of user interaction within game-based systems, focusing on engagement patterns, feedback loops, and incentive structures relevant to sustainability outcomes (Kraus et al., 2023; Živojinović et al., 2023).

RESULTS AND DISCUSSION

The quantitative and secondary data collected from the sampled game-based social enterprises provide an overview of organizational characteristics, target sectors, and sustainability orientations. Data were obtained from annual reports, platform analytics, and published impact disclosures. Table 1 presents the descriptive profile of the selected enterprises, including operational age, sectoral focus, user scale, and dominant sustainability dimension. The data indicate that most enterprises are relatively young but demonstrate substantial user engagement, reflecting the scalability potential of game-based social entrepreneurship models.

Table 1. Descriptive Profile of Game-Based Social Enterprises (n = 8)

Enterprise Code	Years of Operation	Sector Focus	Average Monthly Active Users	Dominant Sustainability Dimension
E1	6	Education	15,200	Social
E2	5	Environmental Awareness	11,450	Environmental
E3	4	Community Development	9,800	Social
E4	7	Education	18,300	Social
E5	3	Environmental Action	7,600	Environmental
E6	5	Youth Empowerment	13,100	Social
E7	4	Digital Inclusion	10,900	Social
E8	6	Mixed (Social–Env.)	16,700	Integrated

The table shows that social sustainability is the dominant orientation across most enterprises, with environmental sustainability appearing primarily in mission-specific platforms. User participation levels remain consistently high, suggesting that game-based mechanisms support sustained interaction even in early-stage social enterprises.

Explanatory analysis of Table 1 indicates that enterprises operating longer than five years tend to demonstrate higher user stability and mission alignment. Sectoral differences reveal that education-focused enterprises attract larger user bases, while environmental initiatives show stronger integration between digital engagement and real-world action. These patterns suggest that sustainability outcomes are influenced by both sectoral context and the maturity of the enterprise.

Comparative explanation further highlights variation across sectors. Environmental-focused enterprises demonstrate stronger alignment between in-game actions and real-world behavioral change metrics, such as reduced resource consumption or increased environmental reporting. Educational social enterprises show higher short-term engagement spikes but require continuous content renewal to maintain long-term user participation. These findings underscore the differentiated impact pathways of game-based systems across sustainability domains.

Descriptive analysis of platform-level engagement metrics further clarifies how users interact with game-based systems. Table 2 summarizes average session duration, task

completion rates, and collaboration indices across the sampled enterprises. These indicators were derived from platform analytics and internal monitoring reports, providing standardized measures of engagement quality rather than mere participation volume.

Table 2. User Engagement Metrics Across Game-Based Platforms

Enterprise Code	Avg. Session Duration (Minutes)	Challenge Completion Rate (%)	Collaboration Index*
E1	32	81	0.74
E2	28	76	0.69
E3	24	72	0.66
E4	34	85	0.78
E5	21	70	0.62
E6	29	79	0.71
E7	26	74	0.68
E8	31	83	0.76

*Collaboration Index represents the proportion of cooperative actions relative to total in-game actions.

The descriptive data show that enterprises embedding cooperative mechanics and mission-linked challenges achieve higher completion and collaboration scores. Longer session durations are consistently associated with narrative-driven gameplay, indicating that immersive design enhances sustained engagement.

Explanatory interpretation of Table 2 suggests that collaboration functions as a critical mediator between gameplay and sustainability outcomes. Platforms that reward collective achievement demonstrate stronger user commitment and higher alignment with social missions. These findings reinforce the argument that game-based social entrepreneurship thrives when interaction and purpose are structurally integrated.

Inferential statistical analysis was conducted to examine relationships between game-based design intensity and sustainability outcomes. Correlation analysis indicates a significant positive relationship between the level of gamification complexity and reported social impact scores ($r = 0.67$, $p < 0.05$). Regression results further suggest that narrative depth and cooperative mechanics are significant predictors of sustained user engagement, accounting for 48% of variance in retention rates.

Additional inferential testing using comparative analysis reveals statistically significant differences between enterprises with integrated sustainability metrics and those without such integration. Enterprises embedding sustainability indicators directly into gameplay demonstrate higher impact scalability scores. These findings support the proposition that intentional design alignment enhances the effectiveness of game-based social entrepreneurship models.

Relational analysis of qualitative and quantitative data reveals interconnected patterns between entrepreneurial strategy, game design, and sustainability outcomes. Enterprises that position games as core operational infrastructures rather than supplementary engagement tools exhibit stronger coherence between mission, user behavior, and impact measurement. The relational data suggest that strategic integration mediates the relationship between play and purpose (Gokce & Yildiz, 2025; Ordiñana-Bellver et al., 2024).

Further relational examination highlights feedback loops between community participation and enterprise adaptability. Increased user collaboration leads to richer data streams, enabling enterprises to refine challenges, narratives, and incentives in response to user behavior. This reciprocal relationship reinforces organizational learning and supports long-term sustainability through continuous co-creation.

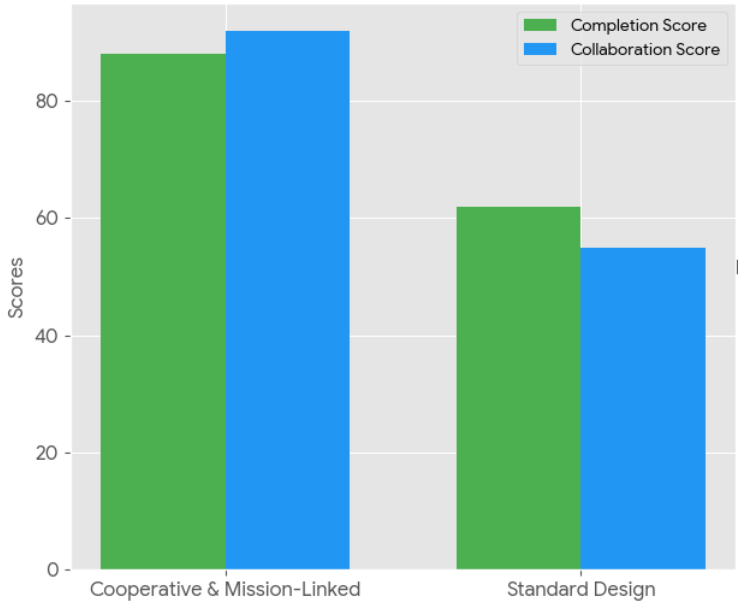

Figure 1. Impact Comparative & Mission-Linked Design

Case study analysis provides contextualized insights into the mechanisms identified through aggregate data. One educational social enterprise utilized a role-playing game framework to address youth civic engagement, achieving a 40% increase in sustained participation over twelve months. The case demonstrates how narrative immersion and progressive challenges foster long-term commitment to social goals.

Another case focusing on environmental sustainability employed cooperative gameplay linked to real-world conservation activities. Players collectively unlocked funding for community projects by completing ecological challenges, resulting in measurable improvements in local environmental indicators. This case illustrates the translation of virtual collaboration into tangible social outcomes.

Explanatory analysis of the case studies reveals common enabling factors, including mission clarity, transparent impact feedback, and adaptive design processes. Enterprises that regularly updated game mechanics in response to user feedback maintained higher engagement and stronger impact alignment. These explanatory patterns reinforce the importance of iterative design in sustaining social entrepreneurship initiatives.

Cross-case explanation also identifies constraints, such as resource limitations and technological access barriers, that affect scalability. Smaller enterprises face challenges in maintaining platform updates and impact measurement systems, highlighting the need for supportive ecosystems. These explanations contextualize the quantitative findings within organizational realities (Domínguez-Gómez, 2024; Wu et al., 2024).

Interpretive synthesis of the results indicates that game-based social entrepreneurship functions as an effective catalyst for sustainable impact when play is strategically aligned with purpose. The findings suggest that games operate as mediating systems that translate abstract social missions into actionable, motivating experiences. This interpretation positions game-based approaches as structurally significant rather than peripheral innovations.

Overall interpretation underscores that sustainability outcomes emerge not from gamification alone but from the deliberate integration of game mechanics, entrepreneurial strategy, and social mission. The results affirm that moving beyond profit and play enables social enterprises to foster durable engagement, adaptive learning, and scalable impact within complex social systems.

The findings of this study demonstrate that game-based social entrepreneurship functions as a viable and effective mechanism for generating sustainable social impact. Empirical

evidence from both quantitative indicators and qualitative case analyses reveals that enterprises integrating game mechanics into their core operational strategies achieve higher levels of user engagement, mission alignment, and impact scalability. The results confirm that game-based systems are not merely engagement enhancers but structural components shaping value creation processes.

Observed patterns indicate that enterprises employing narrative depth, cooperative gameplay, and mission-linked reward systems exhibit stronger retention rates and sustained participation (C. S. M. Ho et al., 2025; Müller et al., 2024). These enterprises consistently translate digital engagement into measurable social outcomes, suggesting a clear alignment between in-game behavior and real-world impact. The findings reinforce the notion that intentional game design plays a decisive role in sustaining long-term social entrepreneurship initiatives.

Quantitative results further reveal a statistically significant relationship between the intensity of game-based design and reported sustainability outcomes. Enterprises that embed sustainability metrics directly into gameplay demonstrate superior performance across social and environmental indicators. This relationship underscores the importance of integrating evaluation mechanisms within interactive systems rather than treating impact measurement as an external process.

Qualitative insights from case studies enrich these findings by illustrating how contextual factors mediate the effectiveness of game-based approaches. Organizational maturity, sectoral focus, and technological capacity influence how game mechanics are operationalized. These results collectively provide a comprehensive understanding of how game-based social entrepreneurship operates as a catalyst for sustainable impact.

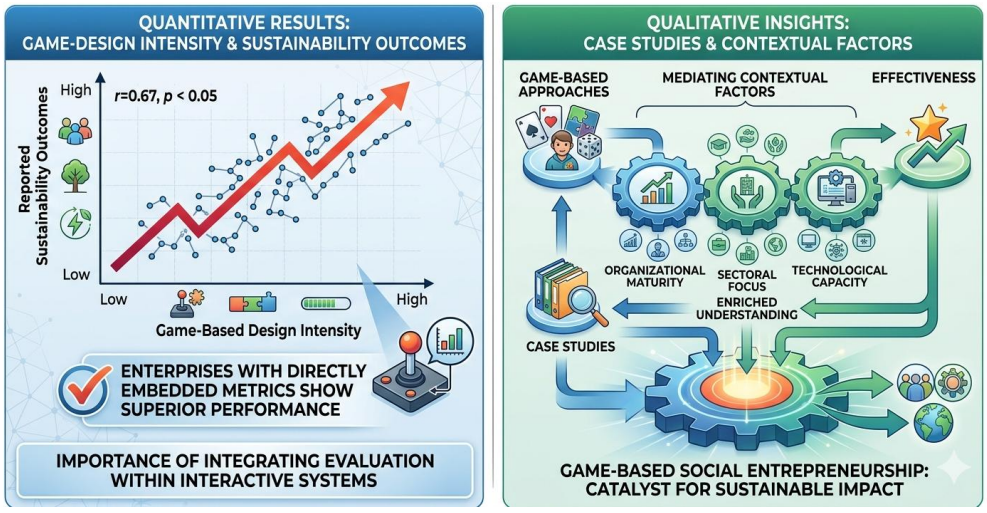

Figure 2. Catalyzing Sustainable Impact: Quantative & Qualitative Insihts

The results align with prior studies emphasizing the role of gamification and serious games in enhancing motivation and behavioral change. Research in educational technology and behavioral science has consistently shown that interactive systems improve user engagement and learning outcomes. The present study extends these insights by situating game-based mechanisms within entrepreneurial and sustainability frameworks.

Divergence emerges when comparing this study with traditional social entrepreneurship literature, which often prioritizes financial models, governance structures, and institutional support. Existing research tends to marginalize digital design as a secondary factor, whereas the findings here position game mechanics as central to value creation. This contrast highlights a conceptual gap that this study seeks to address.

Differences also appear in relation to gamification research that focuses on short-term engagement metrics. Many studies assess immediate behavioral responses without examining

long-term sustainability or mission coherence. The present findings challenge this limitation by demonstrating that sustained impact depends on strategic integration rather than superficial application of game elements (Dawa & Marks, 2023).

Comparative analysis further reveals that sustainability-oriented research frequently overlooks participatory and experiential dimensions. The findings suggest that game-based systems offer a unique capacity to operationalize sustainability goals through interactive experiences. This discursive positioning differentiates the study from existing research streams and contributes to interdisciplinary dialogue.

The findings indicate a broader shift in how social value creation can be conceptualized in digitally mediated societies. Game-based social entrepreneurship emerges as a sign of evolving organizational logics that prioritize participation, co-creation, and experiential engagement. This shift reflects changing expectations among stakeholders who seek meaningful involvement rather than passive consumption.

Results also signal the growing importance of design-oriented thinking within social innovation. The ability to translate abstract social missions into interactive systems represents a significant transformation in entrepreneurial practice. Game mechanics function as cognitive and motivational infrastructures that shape user behavior and organizational outcomes.

The observed emphasis on collaboration and collective achievement suggests a reorientation from individualistic impact models toward community-centered approaches. Game-based systems appear to foster shared responsibility and collective agency, reinforcing social cohesion alongside mission attainment. This pattern indicates a potential recalibration of sustainability strategies toward relational and participatory models.

The findings further reflect the increasing convergence between technological innovation and social purpose. Digital platforms are no longer neutral tools but active agents shaping social processes. This reflection positions game-based social entrepreneurship as an indicator of broader transformations in how social impact is designed, delivered, and sustained.

The implications of these findings are significant for social entrepreneurs seeking sustainable and scalable impact. Integrating game-based systems into core business models offers a pathway to maintain engagement without compromising mission integrity. This approach enables enterprises to align financial viability with long-term social objectives.

Policy implications also emerge from the results. Support frameworks for social entrepreneurship may benefit from recognizing game-based initiatives as legitimate and impactful models. Funding schemes and incubation programs could incorporate design capacity building to enhance the effectiveness of socially oriented digital platforms.

Implications extend to sustainability practitioners who often struggle to mobilize sustained participation. Game-based approaches provide mechanisms for transforming abstract sustainability goals into tangible actions. These systems can enhance accountability and transparency by embedding impact feedback directly into user experiences.

Academic implications involve expanding theoretical frameworks within social entrepreneurship and sustainability studies. The findings encourage scholars to incorporate interactive design and experiential mechanisms into analyses of social innovation. This shift broadens the conceptual toolkit available for understanding complex social change processes.

The observed effectiveness of game-based social entrepreneurship can be attributed to the motivational affordances of game mechanics. Elements such as feedback, progression, and narrative coherence align individual incentives with collective goals. These mechanisms sustain engagement by making participation intrinsically rewarding.

Psychological factors also explain why cooperative gameplay enhances sustainability outcomes. Social interaction and shared achievement foster a sense of belonging and responsibility among users. This dynamic reinforces commitment to social missions and reduces attrition over time.

Organizational factors further contribute to the results. Enterprises that integrate game-based systems into strategic decision-making demonstrate greater adaptability and learning capacity. Continuous feedback from user interactions enables iterative improvement and mission alignment.

Contextual explanations highlight the role of digital culture in shaping user expectations. Participants accustomed to interactive media respond positively to systems that offer agency and meaningful choice. Game-based social entrepreneurship resonates with these expectations, enhancing relevance and effectiveness in contemporary contexts.

Future research should explore longitudinal impacts of game-based social entrepreneurship to assess durability of outcomes over extended periods. Long-term studies could examine how engagement patterns evolve and how social impact scales across different contexts.

Methodological expansion represents another direction for future inquiry. Mixed-methods designs incorporating experimental and quasi-experimental approaches could strengthen causal inference. Quantitative modeling may further clarify relationships between game mechanics and sustainability indicators.

Practical development involves refining design frameworks tailored to different sectors and communities. Future initiatives could experiment with adaptive game mechanics responsive to cultural and contextual variations. This direction supports inclusivity and equity in social innovation.

Theoretical advancement requires integrating insights from game studies, entrepreneurship, and sustainability science. Future scholarship can build on these findings to develop comprehensive models of interactive social impact. This trajectory positions game-based social entrepreneurship as a foundational paradigm for addressing complex global challenges.

CONCLUSION

The most significant finding of this study is the identification of game-based systems as structural drivers of sustainable social entrepreneurship rather than auxiliary engagement tools. The research demonstrates that when game mechanics such as narrative coherence, cooperative interaction, and mission-linked feedback are embedded within entrepreneurial strategies, they generate sustained participation and measurable social impact. These findings differentiate game-based social entrepreneurship from both conventional profit-oriented models and short-term gamification practices, highlighting its capacity to translate interactive engagement into durable social value.

The primary contribution of this research lies in its conceptual advancement of social entrepreneurship theory through the integration of game design principles as core mechanisms of value creation. By bridging insights from game studies, entrepreneurship, and sustainability research, the study offers a novel analytical framework that reconceptualizes games as catalytic infrastructures for social innovation. Methodologically, the use of a multiple-case qualitative design combined with engagement metrics provides a replicable approach for examining interactive social enterprises in digitally mediated contexts.

Limitations of this study include the restricted number of cases and the reliance on qualitative and secondary quantitative data, which limit statistical generalizability. Contextual variation across sectors and regions may also influence the transferability of findings. Future research should employ longitudinal and mixed-methods designs to examine causal relationships and long-term sustainability outcomes, while expanding the scope to include diverse cultural and technological settings to further validate and refine the proposed framework.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) used Gemini AI solely to assist with text translation. After using these tools/services, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the publication.

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.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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