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Interoperability Challenges for Digital Assets in Gamichain Ecosystems: Barriers, Opportunities, and Strategic Directions

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ABSTRACT

The convergence of gamification and blockchain, known as Gamichain, has emerged as a transformative paradigm in digital business, combining behavioral incentives with decentralized technology to create transparent, engaging, and ownership driven ecosystems. Within these systems, digital assets such as tokens, NFTs, and governance coins act as key enablers of value creation, loyalty, and user participation. However, despite their potential, Gamichain ecosystems face significant interoperability challenges caused by blockchain fragmentation, incompatible standards, and limited cross chain asset transferability, resulting in poor user experience and slow adoption. The objective of this study is to analyze the main barriers to interoperability in Gamichain ecosystems, review existing technological and business solutions, and propose strategic directions for building seamless cross platform environments that enable digital asset mobility and sustainable growth. Using a conceptual and comparative case study approach, the research integrates insights from academic literature, industry reports (including Deloitte, PwC, and the World Economic Forum), and practical cases such as Axie Infinity, Starbucks Odyssey, and Cosmos. The analysis applies the Technology Adoption Model (TAM), interoperability maturity frameworks, and SWOT analysis to identify patterns and potential pathways. The findings reveal that the lack of universal token standards, bridge vulnerabilities, and platform lock-ins are among the main obstacles to interoperability, while initiatives such as Polkadot and Cosmos demonstrate promising progress. This paper concludes by proposing a multi layered framework spanning technical, user experience, governance, and regulatory dimensions to guide the development of interoperable and trustworthy Gamichain infrastructures that balance innovation, user sovereignty, and ecosystem trust.

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1. INTRODUCTION

In the modern era of digital transformation, businesses are constantly seeking innovative ways to engage users, build trust, and create sustainable value. One emerging concept that embodies this evolution is Gamichain, the convergence of gamification and blockchain technology [1, 2]. Gamichain represents a new

digital business model that integrates game design principles such as challenges, rewards, and progression systems with the decentralized nature of blockchain. This combination enables organizations to foster user participation, enhance transparency, and establish digital ecosystems where users are not only participants but also verified owners of their achievements and assets.

Digital assets play a central role in supporting the functionality and value exchange within Gamichain ecosystems. These assets include non-fungible tokens (NFTs) that represent unique ownership of digital items, loyalty tokens that incentivize user engagement and reward participation, and governance coins that allow users to contribute to decision-making processes [3]. Together, these elements redefine how users interact with digital platforms, transforming them from passive consumers into active stakeholders with measurable digital ownership.

Despite its innovative potential, the Gamichain ecosystem faces significant challenges, particularly in the area of interoperability. The current blockchain environment remains highly fragmented, with most networks operating in isolation. This fragmentation leads to non transferable digital assets, limited connectivity between platforms, and poor user experience. As a result, the full potential of Gamichain, where assets and data can move freely across different ecosystems, has yet to be fully realized.

Based on this issue, several research questions arise. What are the main interoperability challenges facing Gamichain ecosystems? How do these challenges impact user adoption, sovereignty, and business models? And what technical, business, and policy strategies can be implemented to overcome these barriers? This study seeks to answer these questions by examining the current state of Gamichain interoperability and proposing strategic directions to enhance cross chain collaboration and user experience [4]. The structure of this paper begins with a review of relevant literature, followed by the research methodology, discussion, and analysis of identified challenges. The final sections present a proposed strategic framework, key recommendations, and concluding reflections on the future of interoperable Gamichain ecosystems [5].

2. LITERATURE REVIEW

Gamification and blockchain are two complementary concepts in the modern digital landscape. Gamification, refers to the application of game elements in non game contexts to enhance user engagement and motivation. Meanwhile, blockchain introduces a transparent, secure, and decentralized system for recording and verifying digital transactions [6]. The combination of these two technologies, known as Gamichain, creates additional value by offering verifiable rewards that hold real world and economic value for users. According to Chou (2019), the synergy between gamification and blockchain strengthens user loyalty and builds trust in digital systems, as every user action can be validated through blockchain mechanisms [7].

In the context of Gamichain, digital assets play a crucial role as representations of value within the ecosystem. These assets can be classified into several categories: fungible tokens such as Bitcoin or stablecoins that hold equal value, non fungible tokens (NFTs) that are unique and non interchangeable, and semi fungible or governance tokens that grant specific rights to their holders [8, 9]. Tapscott and Tapscott (2020) explain that each of these asset types serves different functions in Gamichain from serving as a medium of exchange to representing status symbols or providing participation rights in community governance.

Blockchain interoperability is a key aspect that determines the success of Gamichain ecosystems. Interoperability refers to the ability of different blockchain networks to communicate and exchange data securely [10, 11]. According to Buterin (2021), the main goal of interoperability is to create a connected ecosystem where assets and information can move across networks seamlessly. Current approaches include cross chain bridges, layer 2 solutions, multi chain wallets, and interoperability protocols such as Polkadot, Cosmos, and LayerZero. These technologies enable the transfer of digital assets between platforms while improving efficiency and user experience [12].

Despite these advancements, Web3 adoption still faces significant challenges. Fragmentation among blockchain networks forces users to manage multiple wallets and interfaces, reducing overall usability [13, 14]. Additionally, the lack of standardized security measures and regulatory uncertainty remain major obstacles for businesses seeking to adopt these technologies. According to Deloitte (2023), the key barriers to Web3 adoption lie in user experience (UX) complexity and the unclear legal framework surrounding digital ownership and data protection.

Several studies and real world projects have begun implementing Gamichain concepts, including Axie Infinity, Starbucks Odyssey, and The Sandbox. Axie Infinity combines gameplay with a token based economy,

while Starbucks Odyssey integrates NFTs as part of its customer loyalty program [15, 16]. However, these projects still face interoperability limitations across platforms. Unlike Polkadot and Cosmos, which are designed specifically for interoperability, many commercial Gamichain projects remain closed systems that restrict cross ecosystem asset transfers. This highlights the need for further development to enable Gamichain ecosystems to operate in a more open, connected, and sustainable manner [17, 18].

3. METHODOLOGY

This study adopts a conceptual and comparative case study approach to analyze the interoperability challenges within Gamichain ecosystems. The conceptual method is used to integrate theories of gamification, blockchain, and interoperability, while the comparative case study examines how different platforms address or fail to address these challenges. The combination of both approaches allows for a deeper understanding of how technical, business, and policy factors interact in shaping the success of interoperable Gamichain systems [19].

The data used in this research are collected from various secondary sources, including academic journals, industry reports, and project documentation. Academic literature on blockchain interoperability provides theoretical grounding, while consulting reports from PwC, Deloitte, Gartner, and the World Economic Forum (WEF) offer insights into real-world implementation and strategic perspectives [20, 21]. Additionally, case studies from both interoperable platforms such as Cosmos and Polkadot, and non-interoperable ones like Starbucks Odyssey and Axie Infinity, are analyzed to compare their strengths, weaknesses, and scalability potential.

For the analytical framework, this study applies the Technology Adoption Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) to assess how interoperability influences user acceptance and experience within Gamichain applications [22, 23]. Furthermore, the Interoperability Maturity Model is used to evaluate systems at technical, semantic, and organizational levels. To complement this, a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) is conducted to map the strategic positioning of interoperability efforts within the Gamichain industry. This mixed analytical approach ensures that both theoretical understanding and practical insights are addressed comprehensively, providing a holistic framework for assessing interoperability in digital business ecosystems.

4. RESULT AND DISCUSSION

4.1. Technical Challenges

One of the most significant barriers to achieving full interoperability in Gamichain ecosystems lies in the technical layer. Despite the existence of widely used token standards such as ERC-20 and ERC-721, there is still no universal protocol that ensures consistent functionality across different blockchains [24]. This lack of standardization complicates asset transfers and increases the risk of incompatibility between systems. Bridge technologies, which connect separate blockchains, often introduce additional security vulnerabilities [25]. For instance, several high-profile cross-chain bridge hacks have demonstrated the risks of transferring value across chains without sufficient auditing and security layers. Moreover, scalability remains a critical issue, as processing high transaction volumes across multiple chains often leads to latency and elevated gas fees. From a user perspective, these technical complexities result in fragmented experiences, forcing users to manage multiple wallets and transaction processes across networks [26].

4.2. Business Challenges

From a business standpoint, interoperability challenges often stem from strategic and economic considerations rather than purely technical ones. Many companies intentionally create closed ecosystems to maintain control over user data, loyalty programs, and transaction fees. This “platform lock-in” strategy discourages interoperability, as firms fear losing competitive advantage or customer engagement. Additionally, integrating multiple blockchains requires substantial investment and technical expertise, which smaller businesses may find difficult to justify. The lack of shared incentives among ecosystem participants also hinders collaboration. Without a unified business model that aligns value creation across platforms, interoperability remains an underdeveloped opportunity rather than a standard practice.

4.3. Regulatory and Ethical Challenges

Interoperability in Gamichain systems also introduces complex legal and ethical considerations. Since blockchain operates across borders, compliance with Know Your Customer (KYC) and Anti-Money Laundering (AML) regulations varies by jurisdiction, creating uncertainty for global applications. When digital assets move across different chains, ensuring data privacy and ownership rights becomes even more challenging. Regulators are increasingly concerned about liability in cases of cross-chain transaction failures or smart contract exploits. Without clear frameworks for accountability and consumer protection, businesses face significant legal risks that can undermine user trust and adoption. Therefore, achieving interoperability requires not only technical innovation but also policy harmonization and regulatory collaboration.

4.4. Case Insights

Several case studies highlight the diverse approaches to interoperability in the Gamichain landscape. Cosmos and Polkadot serve as pioneering examples of blockchain architectures designed specifically for cross-chain communication. Cosmos employs the Inter-Blockchain Communication (IBC) protocol, while Polkadot uses parachains to facilitate scalable and secure interactions between networks. These systems exemplify technical solutions to the interoperability challenge. In contrast, commercial applications such as Starbucks Odyssey and Axie Infinity operate within more restricted environments. Starbucks Odyssey, while innovative in its use of NFTs for customer loyalty, functions as a closed system with limited asset portability. Similarly, Axie Infinity's Ronin sidechain achieves partial interoperability but has faced major security vulnerabilities, including one of the largest bridge hacks in blockchain history. These cases illustrate the trade-offs between control, openness, and security in building interoperable Gamichain ecosystems.

4.5. Proposed Strategic Framework

To address these challenges, this paper proposes a multi-layered interoperability framework for Gamichain ecosystems. The Technical Layer should prioritize secure and standardized cross-chain mechanisms through audited bridges, wrapped assets, and improved token standards that enhance compatibility across networks. The User Experience Layer should focus on developing intuitive multi-chain wallets and seamless onboarding processes that abstract away technical complexity for end users. The Governance Layer can utilize decentralized autonomous organizations (DAOs) to enable cross-chain decision-making and align incentives among stakeholders. Finally, the Regulatory Layer must embrace a "compliance-by-design" approach, integrating legal and ethical safeguards into the architecture of interoperable systems. Together, these layers create a holistic model that balances innovation, security, and accessibility, paving the way for sustainable Gamichain adoption across industries.

5. MANAGERIAL IMPLICATIONS

6. CONCLUSION

The integration of gamification and blockchain, known as Gamichain, has introduced a new paradigm for digital business models by merging engagement driven design with decentralized value systems. However, the success of this innovation depends heavily on achieving true interoperability across blockchains and platforms. This paper finds that despite significant progress in blockchain technology, interoperability remains one of the most pressing barriers to widespread adoption. The lack of universal standards, security vulnerabilities in cross-chain bridges, and fragmented user experiences have limited the potential of Gamichain ecosystems to deliver seamless and trust-based interactions.

From a business perspective, platform lock in and misaligned incentives between networks prevent companies from fully embracing cross platform integration. Meanwhile, regulatory uncertainty, particularly concerning data privacy, consumer protection, and jurisdictional compliance, adds further complexity to interoperability initiatives. These challenges collectively undermine user sovereignty and hinder the scalability of Gamichain ecosystems. Without effective interoperability, users cannot truly own, transfer, or monetize their digital assets across multiple environments, reducing the overall utility and attractiveness of Gamichain-based products.

To overcome these limitations, this paper proposes several key recommendations. Investment in interoperability protocols such as Cosmos, Polkadot, and LayerZero should be prioritized, as these infrastructures enable secure and scalable cross chain communication. Standardized token frameworks and universal identity layers are needed to ensure consistent functionality and portability of assets. Business alliances across

industries should be encouraged to develop shared ecosystems for loyalty, rewards, and governance. Global regulatory clarity must also be pursued to establish compliance standards and promote trust in decentralized digital economies.

In conclusion, achieving interoperability is not merely a technical milestone but a strategic imperative for the next evolution of digital business. The proposed multi layered framework in this study provides a roadmap for building interconnected Gamichain ecosystems that balance innovation, security, and accessibility. Future research should empirically test interoperable Gamichain use cases, explore AI driven interoperability mechanisms, and develop governance models that enable sustainable collaboration across multi-chain environments.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: KB; Methodology: LK; Software: YS; Validation: KB and LK; Formal Analysis: HK and JH; Investigation: KB; Resources: LK; Data Curation: LK; Writing Original Draft Preparation: YS and HK; Writing Review and Editing: YS and HK; Visualization: LK; All authors, KB, LK, YS, HK, and JH, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

REFERENCES

[1] V. Buterin, "On interoperability and cross-chain communication in blockchain systems," 2021.

[2] Y.-K. Chou, *Actionable Gamification Beyond Points Badges and Leaderboards*. Octalysis Media, 2019.

[3] Deloitte, "Web3 and blockchain adoption building trust in digital ecosystems," 2023.

[4] N. Wijesekara and P. A. D. Shehan, "A review on blockchain based gaming existing insights deficits and emerging avenues," *Journal of Applied Research in Electrical Engineering*, vol. 4, no. 1, 2025.

[5] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness defining gamification," in *Proceedings of the 15th International Academic MindTrek Conference*. ACM, 2011, pp. 9–15.

[6] IBM, "Blockchain for business a practical guide to trust and transparency," 2022.

[7] W. Arafani, "Using gamification through proprofs in learning a systematic literature review," *Indonesian Journal of STEM Education*, vol. 7, no. 1, pp. 29–39, 2025.

[8] N. P. L. Santoso, "ilearning education based on gamification blockchain," *Indonesian Journal of Electrical Engineering and Computer Science*, 2022.

[9] PwC, "Time for trust the trillion dollar reasons to rethink blockchain," 2022.

[10] D. Tapscott and A. Tapscott, *Blockchain Revolution How the Technology Behind Bitcoin and Other Cryptocurrencies is Changing the World*. Penguin Random House, 2020.

[11] A. G. Prawiyogi, Q. Aini, N. P. L. Santoso, N. Lutfiani, and H. L. J. Juniar, "Blockchain education concept 4.0 student centered ilearning blockchain framework," *JTP Jurnal Teknologi Pendidikan*, vol. 23, no. 2, pp. 129–145, 2021.
[12] A. Stibe, D. Sceulovs, Y. Zhang, and J. Li, "Gamified daos as blockchain based catalysts for prosocial and environmentally oriented," in *Mobile Web and Intelligent Information Systems 19th International Conference MobiWIS*, 2023, p. 38.
[13] World Economic Forum, "Interoperability in blockchain ecosystems pathways to trusted digital infrastructure," 2023.
[14] Cosmos Network, "The internet of blockchains whitepaper," 2022.
[15] S. K. Mahardikha, M. Yusuf, and A. A. Musdad, "Development of learning media based on gamification of hijayyah letters in elementary schools," *JTP Jurnal Teknologi Pendidikan*, vol. 25, no. 1, pp. 29–41, 2023.
[16] J. Han, "Smart city as an emerging new regional industry an open innovation perspective in sejong smart city initiative," in *SOI and DEMI of UNINA University Conference*, 2023, p. 69.
[17] S. S. Mohammed Abdul, A. Shrestha, and J. Yong, "Toward the mass adoption of blockchain cross industry insights from defi gaming and data analytics," *Big Data and Cognitive Computing*, vol. 9, no. 7, p. 178, 2025.
[18] H. SbitI, "Interoperability incentives and adoption stablecoins for the future of digital commerce," 2024.
[19] Polkadot, "Polkadot enabling cross chain composability," 2022.
[20] Polygon Labs, "Polygon 2.0 the value layer of the internet," 2023.
[21] Sky Mavis, "Axie infinity whitepaper play and earn digital ecosystem," 2022.
[22] The Sandbox, "Empowering creators in the metaverse official documentation," 2023.
[23] Starbucks, "Starbucks odyssey reinventing loyalty through nfts," 2023.
[24] S. Merena and P. Chinnasamy, "Challenges and opportunities of blockchain," in *Blockchain Technology for the Engineering and Service Sectors*, 2026, pp. 57–86.
[25] K. Zhu, F. Wu, F. Wang, T. Shen, H. Wu, B. Xue, and Y. Liu, "Blockchain-based digital asset circulation a survey and future challenges," *Symmetry*, vol. 16, no. 10, p. 1287, 2024.
[26] L. Yang, S. T. Ni, Y. Wang, A. Yu, J. A. Lee, and P. Hui, "Interoperability of the metaverse a digital ecosystem perspective review," *IEEE Engineering Management Review*, 2025.