Blockchain in Educational Gaming: Navigating Opportunities and Challenges

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***Abstract*— This study paper evaluates the incorporation of blockchain technology into educational gaming, offering an in-depth review of its both positive and negative facets. The study delves into the profound influence of blockchain technology on educational experiences, specifically emphasizing the concepts of decentralized ownership, secure data management, and transparent incentive systems. The study aims to offer an in-depth evaluation of both the advantages and disadvantages in order to direct future research, promote well-informed decision-making, and emphasize the importance of solving difficulties in this rapidly changing and developing subject.**

Keywords*— *Blockchain Technology, Educational Games, Learning Empowerment, Decentralization, Transparent Rewards, Innovative Applications

I. Introduction

The digital era has revolutionized various sectors, including education. Among these advancements, educational games have emerged as a pivotal tool in enhancing learning experiences. As we navigate the complex landscape of modern education, the integration of blockchain technology into educational games stands out as another potentially transformative force. The convergence of blockchain technology and educational games represents a new development in the realm of learning and digital engagement. This paper embarks on an exploration of the impact of blockchain technology on educational games, shedding light on the myriad ways it can empower both learners and educators.

In recent years, educational games have evolved beyond mere entertainment, serving as effective tools for imparting knowledge and fostering critical skills. At the same time, blockchain technology has emerged as a powerful catalyst for decentralization, data security, and transparency. The marriage of these two domains brings forth a promising future for education, offering innovative solutions to age-old challenges.

This study embarks on a comprehensive journey through the intersection of blockchain and educational games, investigating practical implementations, success stories, its transformative potential as well as regulatory hurdles. We investigated through different databases using keywords including and a combination of "blockchain", "NFTs", "educational games", "blockchain-based educational games".

Blockchain-enabled educational games, have the capacity to secure data, decentralize ownership, and establish transparent reward systems. The concept of blockchain immutability and trust-building mechanisms will emerge as pivotal in fostering a conducive learning environment. Through case studies and insights, this paper will demonstrate how blockchain technology is not merely a tool but a new way of looking at technology enhanced teaching and learning that has the potential to reshape the very landscape of education. Blockchain Technology

Blockchain, at its core, is a set of connected records secured through cryptographic techniques. It offers a distributed ledger system that maintains a comprehensive and permanent log of exchanges between entities. This ledger is synchronized across various sites utilizing a consensus mechanism, which guarantees the legitimacy of transactions and the synchronization of accounts [1]-[5]. In a decentralized system, consensus nodes are driven by self-interest and prioritize maximizing revenue as their primary objective when participating in data verification and accounting [6].

A Blockchain is a series of interconnected blocks with every block being linked to the preceding block through its prior block hash. The header establishes a sequential relationship. The Genesis Block is the initial block which lacks a preceding block for connection and typically functions as the initial point of the blockchain [7]-[10].

The blockchain technology has garnered significant attention due to its capacity to improve the efficiency, transparency, and effectiveness of transaction processing and data management [11], [12]. The transparency of the Blockchain is accomplished by the process of duplicating transactions which are duplicated

to either machine within the Blockchain network. Each member has the ability to access and view all transactions, which implies that every action is visible to all participants of the Blockchain [13]-[15].

Smart contracts are software applications that are created using open-source programming languages and deployed on the Ethereum blockchain network [16]-[18]. They play a vital role in enabling transactions and guaranteeing their execution along with managing the transferability and ownership of Non-Fungible Tokens (NFTs) [19], [20]. They execute independently and automatically on network nodes, ensuring the secure and decentralized execution of predefined actions based on the data provided in the transaction [21].

Blockchain technology enables the decentralized execution of contemporary smart contracts. These contracts provide reliable service availability and enable automated transactions based on preset parameters [22], [23]. As highlighted by [24] and [25], Smart contracts increase trust by enabling parties to autonomously verify the terms and conditions of a contract, which ensures the integrity of registered blockchain contracts.

Blockchain goes beyond ledger-keeping, and it serves as the foundation for Decentralized Applications (DApps) [26]. These DApps leverage blockchain's distributed ledger for both data storage and the execution of operations [27], [28]. Tokens play a crucial role in multiple DApps, and are specifically distributed for a certain purpose and operate in a similar manner to coupons within a system as they serve as financial incentives to encourage favorable user actions. Users can monetize their contributions by trading tokens acquired as rewards for cryptocurrency or traditional currency [29], [30].

Among these applications, gaming DApps have become a substantial part of blockchain activity [31]. Figure 1 shows that gaming DApps led other DApp categories in the number of unique active wallets (UAWs), with an increase from 5 million in June 2023 to 8 million by November 2023, despite some fluctuations[1].

An additional application of blockchain technologies in the context of videogames is the implementation of Decentralized Autonomous Organizations (DAOs) to enable decentralized governance and ownership of videogames and videogame firms [32]. According to [33] a DAO is an organization whose fundamental operations are automated and follow predefined rules encoded in computer code, without requiring direct human intervention utilizing smart contracts. El Faqir also highlights that one crucial element in the functioning of a DAO is the share token, which serves as a mechanism for decentralized governance. They presented that ownership of these tokens is distributed among the investors, contributors, and users, gradually reducing the concentration of ownership in any single entity's hands. Share token holders possess the capacity to engage in the decision-making process, wherein they can suggest and cast votes on different protocol modifications [34].

[35] Argues that despite all the potential, DAO, as an application of blockchain technology in governance, presents novel challenges that are absent in traditional blockchain systems. Based on professional expertise and empirical research, there are still noticeable disparities between code-based governance and blockchain-based governance. In addition, [36] underscores the critical need for addressing security issues, highlighting that concerns related to performance and security have surfaced in the context of blockchain DAOs.

A. Blockchain Games

The video game sector aligns with the cryptocurrency ecosystem because it fulfills the desire of many gamers to have true ownership of their virtual possessions and the ability to use them across various games [37]-[39]. Blockchain games represent digital online games developed and run on the foundation of blockchain technology [40], [16]. These games operate with smart contracts, automating critical functions like virtual asset management and rule enforcement along with ensuring transparency and immutability within the gaming ecosystem [41]. Smart contracts are responsible for handling and governing the ownership and transactions of virtual in-game items or assets. To access their virtual gaming assets, participants are required to associate their address with the blockchain [40], [42]. The blockchain address, accessed using a wallet program, will function as a distinct identifier and a destination for the virtual assets belonging to the respective participant [43]. Furthermore, these games incorporate incentive mechanisms, such as staking, wherein players are rewarded with in-game assets and tokens, thereby stimulating community expansion and facilitating game content development [31].

Blockchain technology offers compelling applications in the gaming business, enabling the creation of various games with interconnected environments [44]. The primary advantage of a blockchain network lies in the immutability of information, which guarantees that no data can be altered or removed. This feature was implemented in the game with its own set of rules: it is only permitted to input data within the current block and prior to validation, and once the block is validated, it becomes immutable [45], [8], [46].

In addition, smart contracts enable direct, intermediary-free transfers of in game non-fungible tokens [47], [48]. NFTs utilize smart contracts to guarantee authenticity and resistance to tampering, enhancing in-game experiences by offering exclusive assets [49]-[53]. Some examples of NFT use cases in games encompass the acquisition and distribution of exclusive in-game items, collectibles, user-generated objects, gifts, or signed items by eSport players or streamers [54]. As an example, the famous crypto game, Axie Infinity includes both a governance token, AXS, and a utility token, SLP. Although these tokens possess a purpose within the game, AXS has also gained value as an investment for speculators. The speculative value arises from Axie's DAO, consisting of Sky Mavis and other AXS holders, which receives a 4.25% portion of all transactions occurring on the Axie NFT marketplace [32].

[1] https://dappradar.com/

[40] highlighted that the ownership feature of virtual assets in blockchain-based games contributes to market liquidity and motivates players to engage more actively in the game economy. They also argue that the ability to trade assets across games and also blockchain platforms might enhance the overall gaming experience and economic opportunities for players. According to [55], Blockchain technology fosters incentivized engagement with video games, enabling players to acquire tokens by participating in activities such as playing, evaluating, or promoting games on social media platforms. Moreover, the paper suggests it enhances trustworthiness and responsibility as the records are accessible to the public, promoting responsible behavior among players.

However, according to [56] Munir (2019), while blockchain technology ensures security regarding asset ownership and trade, it is crucial to recognize that online games still possess the vulnerability to hacking and tampering. A violation in traditional online video games does not result in financial repercussions. The sole impact is contained within the game environment; however, the inclusion of incentive items will render offense challenging than it was of traditional online games.

DAOs, as another blockchain feature in gaming industry, are utilized in blockchain gaming guilds, which function as communities where gamers convene to participate in many game-related activities. Within these guilds, users cooperate to advance in games, distribute and trade in-game resources, and collectively create income from their gaming endeavors [57], [58].

Another feature of some blockchain games is Scholarship programs, like those seen in Axie Infinity, leverage smart contracts to assist novice gamers in overcoming financial barriers [59], [60]. Scholarship schemes entail affluent participants, referred to as "managers," lending their Axies to those known as scholars. This provides gamers, especially those from a less fortunate demographic, with the chance to play without any cost. As compensation, the managers receive a share of the scholar's gaming earnings by investing their own capital [61].

Building upon the benefits of blockchain technology in gaming mentioned earlier, [32] asserts that Blockchain technology facilitates the creation of innovative game distribution platforms. Critics argue that centralized platforms facilitate the connection between users and game producers but charge excessively high fees for their services. However, Blockchain technologies offer greater equity and economic viability by minimizing intermediary expenses and promoting a fairer distribution of developers and customers.

On the other hand, [45] highlighted that blockchain gaming has several limitations, notably the absence of control over specific elements such as unwanted or unlawful information. Furthermore, it has been observed that the existing ERC token standards do not effectively integrate with the other layers when it comes to accurately representing a video game asset on the blockchain. As an illustration, only the ERC-721 interface exclusively permits a reference to metadata, which is represented by a single URI that may eventually become outdated. Adding to the complexities, [62] has identified several disadvantages in blockchain games from the user's perspective. These drawbacks encompass issues such as the energy-unsustainable protocols of Ethereum and Bitcoin blockchains, the carbon footprint associated with NFTs, potential fraud risks, legal considerations surrounding NFTs, and the susceptibility to capital flight and money laundering within Crypto-Asset Markets.

In addition, [63] contended that crypto games exhibit certain drawbacks in contrast to traditional games, including simple game rules, limited participation, and a very brief lifespan. Moreover, these games are constrained by the blockchain's performance, and the transaction cost associated with blockchain games is considerable.

B. Educational Games on Blockchain

Game-based learning is a countinuesly developing field within education [64]. Game-based learning is an educational approach that uses a game to teach information and skills in an engaging and hands-on gaming setting [65], [66]. Digital games have attracted significant interest as a means of facilitating learning processes and education, extending beyond their primary function as entertainment media [67], [68].

The utilization of blockchain technology has demonstrated efficacy in several contexts, including the field of education [16]. The process often entails utilizing the essential elements of blockchain, including "blocks" that contain references to the precise learning data. These blocks are protected by ownership and access regulations. In this context, the term " blockchain nodes" refers to the learners and educational institutions [69]. An exemplary instance of blockchain's use in this domain is Sony Global Education, which functions as an educational record storage platform utilizing blockchain technology. This platform not only securely archives students' educational experiences but also provides reliable certification [70]-[72].

The advent of digital learning environments in education has brought about a growing concern for ensuring the trustworthiness, security, and integrity of data. The inherent immutability of Blockchain technologies makes them an ideal tool for securing educational accomplishments and certificates [73]-[75]. The development of decentralized and secure platforms tailored for both students and instructors has the potential to revolutionize the dynamics of learning networks. This transformation holds the promise of establishing secure, open communication networks that facilitate direct interaction among users, eliminating the need for intermediaries [76], [41]. Within the field of education, the implementation of blockchain technology and smart contracts improves several procedures including the management of credentials, transcripts, learning progress, and reputational qualities. Additionally, it facilitates financial transactions [38], [77]-[79]. Also, smart contracts are continuously computed as digital game asset transactions are authenticated by the game participants, making it possible to trace the ownership of assets on the blockchain [16], [80].

Universities have utilized blockchain technology to effectively oversee students' examination records, verify answers, ensure the integrity of records, and enhance consistency as well as security [81]-[83]. Furthermore, the implementation of a student-centered learning process utilizing

Blockchain is anticipated to be crucial in establishing a highly autonomous learning ecosystem [84]. The implementation of blockchain technology in higher education began in 2014 with the University of Nicosia, Cyprus (UNIC) adopting this technology to securely keep and verify its degrees. Additionally, UNIC became the first university to accept bitcoin as payment for tuition fees [85].

Blockchain technology brings innovation to various aspects of education, including protection of intellectual property, reputation management, e-portfolios, and also academic research [86]. One of the key advantages highlighted by [41] is the ease of access to students' educational records. They mentioned by utilizing blockchain, the aim is to eliminate friction and delays caused by complex administrative processes involving multiple levels of management, and this approach promises to streamline record-keeping, ensuring that authorized individuals can access and verify educational data efficiently and securely. Moreover, according to [87], the technology could guarantee that the student who registered for the course completed it and comprehended the content. In addition, the platform could have a payment feature and empower students to create smart contracts for establishing learning practices over the long term.

NFT-driven play-to-earn (P2E) games, commonly referred to as "crypto games", allow players to possess in-game assets such as skins, weapons, digital accessories, characters, and virtual land. [88]-[90]. According to [91], NFTs flourish with art collections but are capable of more, including aiding educators in the promotion of texts and resources. Tokens representing academic transcripts comprise grades, reports, and annual accomplishments. In addition to counseling, token scholarships may be redeemed for online courses, event attendance, and resource visits.

In other educational domains, [92] presents a blockchain game with the purpose of educating cryptocurrency investment, which connects microeconomic decisions with macroeconomic principles. This gamified methodology promotes student comprehension and may be adjusted to different educational environments. They also provided suggestions to improve the user experience in the future iterations of the game. Also, [93] created an instructional blockchain game called Crypto Go, with the purpose of instructing users on symmetric cryptography and its associated mathematical principles. The primary emphasis seems to be on addressing the lack of analog instructional games for cryptography, particularly ones that can be customized for a broad range of individuals with different levels of digital proficiency.

In addition, the use of blockchain technology is extensive in the realm of serious gaming [94]. [95] clarifies the objectives of a serious game (SG) as leveraging serious gaming to enable players to interact with a virtual world. This approach serves three main purposes: developing abilities, adjusting behavior, and stimulating information acquisition.

A serious game (SG) is a game not merely for entertainment but the primary purpose of which is educational and serves a meaningful role [96]. In [97], a serious game that combines elements of online gaming and blockchain technology is introduced for educational purposes. Participants accumulate tokens by engaging in scenario-based games set in a lifelike town, resulting in the creation of Cybersecurity Enhancement through Blockchain . In addition, [41] highlights how blockchain technology can be applied in healthcare related serious games to improve various aspects of security, data management, and reliability, as well as its potential roles in clinical trials, auditing, and regulatory approvals. Another notable example is [98] which employed a combination of Ethereum and Unity 3D technologies to incorporate blockchain functionality into a SG centered around Bromo Mountain tourism. During the experimental phase for this game, various variables were examined on the Ethereum platform to evaluate transaction speed and success rates.

II. Conclusion and Future Work

In conclusion, the integration of blockchain technology into educational games represents a potentially significant advancement in the field of learning technology. This transformative fusion has paved the way for a multitude of benefits that empower both learners and educators. Throughout this study, we have explored the multifaceted advantages that blockchain brings to educational games, shedding light on its potential to revolutionize the learning experience.

Blockchain technology, at its core, provides a secure and decentralized framework that ensures trust, transparency, and immutability. By serving as the foundation for educational games, it introduces a new era of possibilities. Smart contracts, an integral part of blockchain, enable the automation of critical functions such as virtual asset management and rule enforcement. This not only streamlines in-game processes but also instills confidence by granting players genuine ownership of their virtual assets. Additionally, the use of NFTs within blockchain-based games enhances the overall gaming experience by offering exclusive and tamper-resistant digital assets. blockchain technology has the potential to challenge the traditional power structures in the gaming industry by offering alternative distribution models and more democratic forms of governance and ownership.

In the educational realm, blockchain's influence extends to credential management, learning progress tracking, and secure data storage. By utilizing blockchain technologies, institutions can securely store educational data, including certificates and grades, while ensuring the integrity of these records. This innovation has the potential to streamline administrative processes and eliminate delays caused by multi-level administration.

However, it is essential to acknowledge that blockchain technology is not without its challenges. While blockchain gaming offers several advantages, such as decentralization and transparency, it also presents challenges related to content control and the proper representation of game assets within the blockchain ecosystem [45]. Insufficient comprehension of blockchain applications has led to emerging difficulties in implementing blockchain gamification and incentive systems. Furthermore, while blockchain excels in providing security and immutability, it may not be the optimal choice for storing regularly updated data, such as points and prizes. The migration

of data from centralized databases to decentralized public ledgers on the blockchain can result in somewhat sluggish performance and necessitate a substantial financial investment. Moreover, transaction fees are often required to ensure network verification [99].

One area that has not yet been sufficiently studied is how blockchain-enabled educational systems can deal with various governmental regulations related to data privacy. This is particularly problematic since data transparency is one of the fundamental and defining features of current blockchains, while at the same time being hugely problematic in education. A broader adaptation of blockchain technology in the educational sector will require finding standardized ways to operate within strict data privacy frameworks. While the application of Blockchains is extremely promising in principle, making this technology consistent with data privacy regulations within the context of education is therefore an absolute requirement for its practical use.

Reflecting on our findings, blockchain's role in educational games is multifaceted, offering both opportunities and challenges. Future work in this field should focus on addressing these challenges, for example by finding ways to enhance blockchain's suitability for storing frequently updated data in educational games, or by working on ways to satisfy regulatory data privacy frameworks. Additionally, efforts to improve user understanding of blockchain applications are crucial for the successful implementation of blockchain-based educational gaming platforms.

The integration of game design into educational settings is still a relatively new and unexplored trend in terms of its impact on students' learning motives and outcomes [85], [100]. Blockchain technology has ushered in a new era of empowerment in educational games and its potential to provide secure, transparent, and immutable systems has redefined how we approach learning and gaming. As we continue to explore the possibilities and address the challenges, the future of educational games intertwined with blockchain technology appears promising, offering innovative and engaging learning experiences.

Fig. 1. The number of UAWs in each category as of November 2023[2]

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