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Navigating the Future: Blockchain-based Metaverse in Education

Lakmali Karunarathne[1], Swathi Ganesan[2], Nalinda Somasiri[3], Sangita Pokhrel[4]

[1,4]Lecturer In Computer Science & Data Science Department at York St John University London Campus, United Kingdom.

[2]Deputy Associate Dean of Data Science Department at York St John University London Campus, United Kingdom.

[3]Associate Dean of Data Science Department at York St John University London Campus, United Kingdom.

E-mail: [1]l.karunarathne@yorksj.ac.uk, [2]s.ganesan@yorksj.ac.uk, [3]n.somasiri@yorksj.ac.uk, [4]s.pokhrel@yorksj.ac.uk

Abstract

This intricate system of integrating blockchain and metaverse technologies is having a revolutionary impact on the future of education by creating a decentralized system where student records can be securely stored, enabling fully immersive virtual learning environments. Indeed, this integration permits the construction of safe, collaborative, and interactive 3-D learning spaces on demand in action within an ever-shifting virtual environment. Indeed, the convergence of these technologies effectively re-situates and recontextualizes them with regard to change in the way users, learners, and educational organizations interact, implementing innovative and growing boundaries of digital developments in educational practices. This transformation changes the way that traditional systems of education create space for creativity toward reconfigurable thought for changing generations through dynamic adaption to meet the needs of fluid and changing present-day learning environments.

Keywords: Blockchain, Metaverse, educational landscape, Immersive Learning Experience, Decentralised Identity Management (DID), Digital Transformation in Education

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1. Introduction

1.1 Overview of Blockchain Technology

Blockchain was first suggested by Satoshi Nakamoto in 2008 as a Bitcoin management system. As things stand, it has opened as a new technology found for all applications for supply chain, higher education, health care, retail, IoT, and other flagship applications[1] In higher education, blockchain takes part in data security and administration of the student organization and Higher Education Institutes (HEIs), meaning that the transaction is clear and open for decentralised computer networks while tackling problems about amoral misuse and ensuring scalability in online education.[2] A Blockchain is a shared cryptographic ledger where blocks are coupled with time, ordinal hashing, and hash of the predecessor block, registering chains of blocks with their unique hash[3] Additionally, it engages proof of work and proof of stake for real-time consensus synchronisation across transactions and connects to smart contracts, which are programmable entities that guarantee inconsistent enforcement of agreements.[4] Cryptographic techniques are supported by mathematics and game theory to secure the ledger data confidentiality, integrity, and correctness as they transmit among nodes.[5]

1.2 Overview of Metaverse Technology

These metaverses are post-reality possibilities that intermingle virtual digital features with physical reality, forming a persistent multi-user platform.[6] Incorporating leading-edge technologies, these alternate realities, defined in AR and VR, develop immersive social settings like VR platforms, MMORPG games, AR cooperation settings, tools such as Head-Mounted Displays (HMDs), motion input devices, and hand-based input devices offering functionalities like object recognition, sound and speech recognition, and content generation.[7] The usual architecture blocks of the Metaverse entail AR and VR for its basis of use, blockchain for security, AI for increased engagement capabilities, and interactivity with IoT devices. This metaverse must be cloud-based to host it and meet its incredibly high demands while contributing to spatial computing and enhancing user experiences with synchronized digital content in a real-world setting with the power of dynamic interaction.

2. Blockchain Technology and Architecture

The blockchain is a decentralized and distributed digital ledger that enables secure, transparent, and immutable records of transactions across the more secure peer-to-peer

networks.[8] It eliminates the need for middlemen by using cryptographic methods to verify and securely store data in a transparent manner, enabling transactions that cannot be trusted, the parties involved in the transaction do not require trust among each other or a central authority.[8] The blockchain ledger is a model consisting of blocks of sequentially connected blocks from a genesis block onward in a never-ending chain. Each block comprises two key logical parts: a block header on the one end and transaction data on the other. The block header furnishes metadata such as the version number, the timestamp, and a cryptographic hash of the previous block, rendering the network an eternal continuity and inalterability.[9]Within the block, the data of transactions will be beautifully arranged as a structure of a Merkle tree for efficient data verification. The Merkle root data is stored in the block header and represents a single value that verifies all the transactions in the block to guarantee the entire data is in place while avoiding having to reference the entire dataset.[10] Hash functions are important in securing and preserving data integrity of the blockchain. So, given an input, a hash function produces a hash or digest of a fixed length. Using the SHA-256 cryptographic hash function, blockchains such as Bitcoin perform the secure hashing of data through a fair amount of mathematics. The design of hash functions assures that if there is a tiny change in the input data- even one bit -an avalanche effect in the hash output will occur. This is the principle that makes the blockchain process unable to be tampered with. In combination with transaction security, hash functions are used in specific consensus algorithms such as Pow, where miners decide on transactions based on their completion of the hash puzzles. That identifies an unmanaged item that, after maintaining the hash target, shows the object of block data that indicates consensus. In this way, blockchain technology has become quite well-known by the way it keeps itself from being changed.[9].

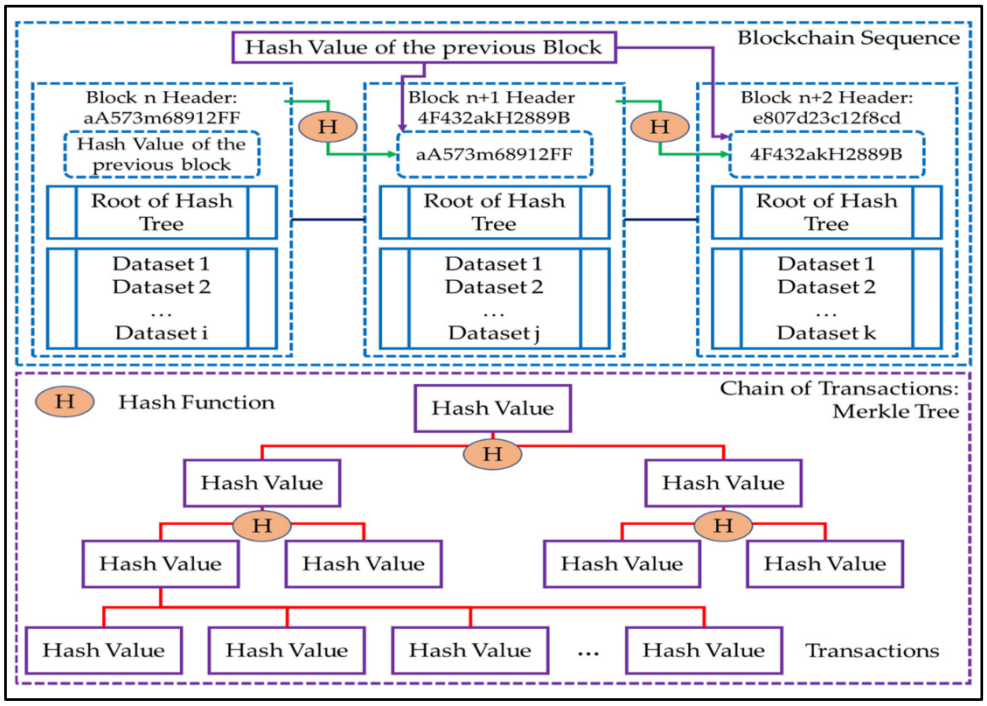

Figure 1. Depicts the Operating Principle of Blockchain.[11]

3. Metaverse Technology and Components

The metaverse constitutes a vast digital ecosystem in which the physical and the virtual worlds merge together to create immersive environments where individuals can cooperate, interact, and engage in many things. Considered a successor to the current internet, the metaverse has generated several technologies to bring about an uninterrupted virtual experience. Some of the essential technologies are mixed reality (MR)/virtual reality (VR), artificial intelligence, and the blockchain, sitting at the metaverse's core to warrant functionality, interactivity, and scalability. In a nutshell, the metaverse should become a nexus for interconnected digital spaces that transition well over the established boundaries, giving new definitions to different sectors of the economy, including entertainment, education, commerce, and healthcare.[12] Augmented reality (AR) is a key component of the metaverse which brings the digital world into the physical universe. This functionality applies to AR devices such as glasses, headsets, and smartphones, which rely on cameras and sensors to scan the real world. AR achieves a seamless fusion of real and digital content by applying image recognition, spatial mapping, and real-time tracking. This technology even allows digital objects to be built that interact with one another, giving one an illusion that these objects blend in with the physical surroundings, as displayed by applications like Pokémon GO. Once in the

metaverse, AR will be of paramount importance in creating hybrid environmental fields whereby users can access virtual data, collaborate on projects, and then stay engaged in entertainment while remaining grounded.[13] While Augmented Reality (AR), in part, makes the world digitized, VR takes us to a location interspersed with completely computer-generated universes. More VR immerses users into such a digital world with visuals that are stereoscopic 3D and sound spatially of a kind that might help us perceive the world lying beyond. Besides, tracking movement enhances the experience by adjusting body movement within a corresponding environment. So, a smooth experience is also felt because of high frame rates and low latency while this approach minimizes any chance of motion sickness. In the metaverse, it will not only play a big role in gaming, but also in working with virtual get-togethers, education, and health services that call for the immersive, true-to-life experience.[14] Solid networking infrastructure is required to accommodate millions of users for engaging in real-time interactions in the metaverse. Low latency in the delivery of content is made possible by technologically sophisticated forms of communication such as 5G and edge computing. Meanwhile, these decentralized systems entail a blockchain for guaranteeing the digital ownership and authenticity of digital goods and services in such an environment. Through the introduction of blockchain technology an economy for the exchange of non-fungible tokens (NFTs) representing, among other things, digital assets such as digital art, virtual lands, or in-game items, was built. Utilizing these technologies, individuals can make money off the digital things that create, thus engendering a self-perpetuating digital economy.[15]

4. Integration of Blockchain and Metaverse Technologies

The strategic and purposeful integration of blockchain and Metaverse Technology by the educational sector deeply contends these technology enhancements for the learning ecosystem. This strategic move seeks to take advantage of the ground-breaking potential of the technologies and revolutionize conventional education models. It is known that they can enhance creativity and successfully address the pressing issues faced by present-day educational institutions.[2]

4.1 Framework for Blockchain-metaverse Integration

Blockchain integration into education in the metaverse may consist of three layers: infrastructure, applications, and user layer.

4.1.1 Infrastructure Layer

Blockchain fundamentally serves as an infrastructure for secure decentralized data management. Public blockchains, for example, Ethereum and Solana, mostly enable smart contract activity since they can scale and run these protocols. Smart contracts serve as a fundamental part of issuing verifiable credentials, taking attendance, and facilitating the settlement of fees. For example, when a student completes a course in a metaverse classroom, a smart contract will justifiably create a blockchain-backed certificate, which can then be posted and shared globally.[15]

4.1.2 Application Layer

This layer interconnects blockchain functionalities with metaverse platforms for the provision of seamless access to academic services. Blockchain-based wallets and Non-Fungible Tokens (NFTs) assist with the secure storage and trading of digital assets like course access, e-books, and virtual lab tools. Tokenized systems could potentially employ a pay-as-you-learn model where learners pay for individual lessons or assessments in cryptocurrencies or educational tokens.[14]

4.1.3 User Layer

This layer will focus on providing great experiences for students and educators. Through decentralized identities (DIDs), students can be able to carry their accredited academic history across metaverse platforms. This saves them from redundant registration processes in one hand while basically securing their private identities. Furthermore, existing DAOs (decentralized autonomous organizations) might hence propel more power in their following favor, allowing students and teachers to co-manage educational metaverse sites through the decision process locally regarding curriculum updates or resource allocation [13]. Figure 2 depicts the framework of the blockchain metaverse integration.

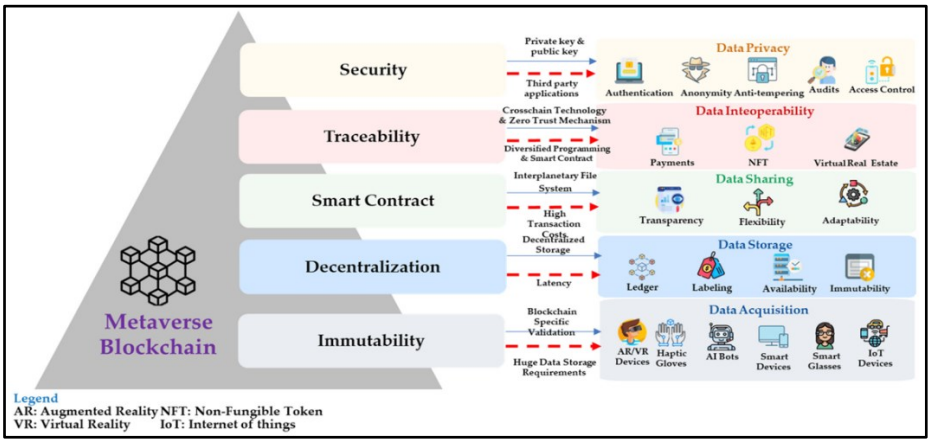

Figure 2. Framework for Blockchain-metaverse Integration [11]

4.2 Algorithm for Blockchain-Metaverse Integration

The education in the metaverse following the integrated efforts of the blockchain is guaranteed through the customization of algorithms that promote a super-secure, operational, and decentralized approach. A major example of an algorithm is the Proof-of-Learning Device (PoL) that certifies and processes awarded blockchain certificates of academic achievements. It helps validate student progress through course completions, virtual lab participation, or test results out of a smart contract. As a milestone is reached and the student experience is initiated further, the system would help in recording this progress in the blockchain and issuing certificates or tokens that are unchangeable. The path offers complete transparency and encouragement for learners to secure that extra credit token needs to be paired with certain qualities and behaviours. [15] An essential connection to the Interoperability Algorithms is the sharing of data, credentials, and assets across differing metaverse platforms and institutions. Blockchain protocols, such as Polkadot and Cosmos, allow for bridges between multiple blockchains, so anyone can keep their academic credentials earned in any metaverse acceptance. With these algorithms, where educational ecosystems could be rendered universally accessible and detach from all institutional silos.[16] Decentralized Identity or DID algorithms are crucial for user privacy protection and guarantee of identities in the digital world. Decentralization boosts identity management wherein students and educators either take their verifiable credentials along with them across virtual worlds or be exposed to data breaches and credential duplications. A DID ladder incorporates blockchain-fixed credentials into the identity of the user, and with this furnishes a smooth proof of authenticity to access the educational environment in the virtual space.[17] Tokenization Algorithms, finally, are most certainly involved in the creation of blockchain-based tokens that duplicate educational assets

such as course access, the right to gain digital resources or various forms of certification; such algorithms enable micro-transactions, making it easy for the exchange of educational assets within the metaverse or virtual economy. Tokenizing the resources allows learning systems to implement ingenious mechanism payments, for instance, pay-as-you-learn; hence, this would also support open access and affordability.[15]

4.3 Implementation Steps for Blockchain-Metaverse Integration

Education integrating blockchain and metaverse requires a systematic approach toward achieving scalability, security, and user-centred functionality. To start with, it has to be first recognized and defined use cases, including credentialing and decentralized resource management, and immersive learning environments. Through blockchain technology-based digital certificates issued; granting the highest standards, the integrity of the academic credentials is preserved while in the metaverse providing virtual classrooms and interactive simulations aided by a system tailored to the specific world of teacher and student for deepening trust and transparency.[18] The next step means the selection and deployment of the blockchain protocol that is appropriate. Public blockchains, like Solana, Avalanche, or Polygon, are the first choice because they can offer their straightforward scalability, productivity, and affordability. Within every other operation for the verification certificates, the privilege to transmit fees, or accomplished progress' followed, they do facilitate smart contract mechanisms or programs. As an example, a smart contract can automatically provide a verified certificate for the completion course, thereby guaranteeing pragmatism and relieving administrative overhead.[19] A mandatory step is then the implementation of DID for secure, sovereign identities of both the candidates and the administration. Popularized as DIDs, these ensure maintaining better privacy of personal credentials. The foreign user gets control over the storage of their own identity and credentials. With all their interconnectivity and accessibility, DIDs cross moderators and providers to ensure smoother user privacy in online access to learning platforms.[20] Blockchain residual tokenization can be done for educational resources such as course content, certifications, and lab tools where this kind of tokenization ratings their presence in digital form, which further appears to be additional benefits and aids in making transactions on a minuscule level and renders a lot of accessibility. For instance, students can have the language and passage secured by the blockchain-based token with which proponents can provide a flexible "Pay-As-You-Succeed" model.[21]

4.4 Successful Integration Example of Blockchain and the Metaverse

4.4.1 Decentraland

Decentraland, a blockchain-based virtual world built upon the Ethereum blockchain, is one of the most-discussed examples of the metaverse being integrated into blockchain. Due to this, Decentraland implements genuine digital ownership since it allows its users to buy, develop, and trade virtual real estate as non-fungible tokens (NFTs). Big brands worldwide such as JPMorgan, Samsung, and Adidas have found their way into Decentraland for digital advertising and client engagement. More than $500 million in land sale transactions have gone through the Decentraland platform, with some selling for millions of dollars. The integration of blockchain ensures transparency in transactions, and smart contracts facilitate the automatic transfer of ownership and monetisation of virtual assets.[22]

4.4.2 Sandbox

The Sandbox is a platform for decentralized gaming that allows users to create, own, and monetize gaming experiences through their NFTs and cryptocurrency SAND. The platform runs on Ethereum and provides users with tools to build and share 3D games and assets, therefore growing into a user-led content ecosystem. Within that model, SAND is used as the ecosystem's cryptocurrency whereby users can earn and spend it.[23]

4.4.3 Axie Infinity

Developed by the Vietnamese studio Sky Mavis, Axie Infinity is a blockchain game that is known for its in-game economy based on Ethereum-based cryptocurrency. In these games, it has been said that cheap labour from countries like the Philippines is used to fuel the system's expansion. Participants in the system are engaged in the collecting and breeding of digital pets that resemble axolotls and are called Axies. The digital creatures are bred and used for battle in the gaming world. Sky Mavis charges a trading fee of 4.25% for Axie trades performed on its marketplace.[24]

4.4.4 Illuvium

A decentralized development studio is making the first Interoperable Blockchain Game (IBG) Universe, featuring various experiences including an open-world exploration game, a city-building simulation of industry, and an auto battler all running on the Ethereum blockchain. Lace up for a stunning sci-fi journey through seven gorgeously crafted alien

environments and uncharted wildernesses to discover the catastrophic events leading to the shattering of Illuvium. There's a lot of work to be done to help the crew who are marooned survive.[25]

5. Future Direction for Integrating Blockchain and the Metaverse in Education

Aiming to enhance cohesion between blockchain technology and the metaverse in education compiles several suggestions and the expected path that might be pursued. First, implementing decentralized identity management (DID) would facilitate data management in the educational field by ensuring privacy and security of users. [26] However, the metaverse provides interactive and immersive virtual environments that are transforming conventional education. These environments allow learning experiences customized to individual learning needs, based on AI capabilities to modulate content delivery. The system develops real-time responsive learning situations that engage students and enhance comprehension. The metaverse nurtures the immersive virtual classrooms for almost a personal and collaborative learning experience keeping in mind the student's needs and requirements. Through the application of kept technologies such as AI, these environments adapt content dynamically maintaining engagement and boosting comprehension.[27] Moreover, the blockchain decentralizes instructional materials, ensuring equal coverage and promoting the originality or integrity of content. The integration of the various technologies may lead to greater global collaboration, and students will be given the resources to network and collaborate with participants from across the globe in shared and dynamically lit-up virtual spaces. Blockchain and the metaverse are reshaping education into a design that is secure, inclusive, and responsive to today's 21st-century learners.[28]

In addition, global collaboration necessitates the extension and interaction of various blockchain networks and metaverse platforms, offering proofs and assets for ease of carrying from one ecosystem to another for the benefit of learners. There should be efforts of research and development to address challenges such as latency, resource demand, and digital equity when developing scalable, secure, and very user-friendly frameworks. Following this direction, the blockchain and the metaverse can fashion a transformative, inclusive educational paradigm ready for the future.

6. Conclusion

The unifying force of blockchain and the metaverse provides revolutionary changes for education in secure, decentralized, and immersive learning environments. Competency in the blockchain will provide transparent and transferable academic credentials, decentralized identity management, and smart-contract-driven learning, while the metaverse will provide interactive, collaborative, and personalised education augmented and virtual reality.This synergy addresses challenges such as educational inclusion, geographical barriers, and cost-effectiveness by enabling decentralised instructional material development, global collaboration, and learner-driven education. Features like tokenization introduce flexible learning models, such as “pay-as-you-learn”, and blockchain interoperability facilitates seamless transfer of credentials across platforms and institutions. Accepting AI, VR, AR, and blockchain will help these institutions instill students with creativity, innovative thought processes, and adaptability to pass through a fast-changing world. The further development and strategic propagation of such technologies will enhance traditional barriers to learning to create a fully decentralized immersive learning ecosystem.

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Author's biography

Lakmali Karunarathne, I am currently working as a lecturer, module director and the academic induction lead. I began my career as a lecturer and program coordinator, honing my leadership and management skills. I served as the head prefect of my school and successfully developed leadership skills. Through these experiences, I honed my abilities in leadership and effectively managed student courses. With a strong foundation in leadership, I have excelled in academia and the technology industry. Transitioning to software development as a software developer, I bridged theory and practice, solving real-world challenges. With an MSC in computer science, I joined York St John University, where I am a lecturer in data science and computer science department. My published research articles on the Internet of Things, Programming languages, Machine Learning and databases demonstrates my passion for teaching and interest in innovative technologies.

Swathi Ganesan, I hold the position of Deputy Associate Dean & Senior Lecturer within the Computer Science and Data Science Department at York St John University in London. In this capacity, I lead course modules in Computer Science and Data Science, serve as a member of the Academic Management Leadership team, and contribute to the School Quality Panel. Beyond my teaching responsibilities, I assume the role of Academic Semester Performance and Quality Lead for the Computing Department. I have a track record of publishing numerous papers and actively engage in Machine Learning and Data Science conferences. Additionally, I've taken on the role of chairing various International Conferences on Machine Learning and Computing, and I collaborate closely with colleagues within the department on research-related initiatives.

Dr Nalinda Somasiri, I am the Associate Dean for Data Science and Computer Science at York St John University, London Campus. Prior to beginning with York St John University in 2020, I was a Solution Architect at Motorola Solutions, UK, from 2006 to 2019, where I delivered innovative and cutting-edge AI & Machine Learning application solutions to the Public and Safety domain within the UK and to international customers. I am an AI, Machine Learning and Blockchain developer, researcher, practitioner, AI and ML specialist as well as a data consultant with over 20 years in the industry. I have worked in companies such as Motorola Solutions (UK), Jaguar Land Rover (UK) and MBDA during my time in the industry. The focus of my current research is on Blockchain, Generative AI and Machine Learning. I have published over 30 journal and conference papers in these fields. I also work closely with AWS, Motorola and IBM on Generative AI and ML research activities