WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Decentralized Education Data Management Using Blockchain

Ms. Snober Iqbal[1], K. SreeNiketh Raj[2], K. Vineeth Reddy[3], Mohd. Mudaseer Mazharuddin[4]

[1]Assistant Professor, Computer Science and Engineering (IOT), Guru Nanak Institutions Technical Campus, Telangana, India
[2,3,4]Computer Science and Engineering (IOT), Guru Nanak Institutions Technical Campus, Telangana, India
[2]rsreeniketh@gmail.com, [3]koppulavineeth2004@gmail.com, [4]mudaseer2753@gmail.com

ABSTRACT –

In today's digital age, student academic data is still largely controlled by educational institutions, which creates major risks and limitations. Centralized systems are vulnerable to data loss due to natural disasters, political instability, or system failures. They also make it difficult for students to access or share their records when participating in exchange programs or pursuing lifelong learning across different platforms. To solve these issues, this paper introduces a decentralized approach where students have full control over their educational data.

Using blockchain technology—specifically the Ethereum public network—and Web3 tools, we present DecentralEduChain, a framework that allows students to securely store and manage their academic records through smart contracts. Educational institutions can interact with these contracts via integrated Learning Management Systems (LMS), enabling both the reading and updating of student records without relying on centralized databases. This system not only enhances security and transparency but also empowers students with ownership of their data, making it easier to share academic credentials across institutions. The paper also outlines the practical steps for implementing the system, including smart contract creation and integration with LMS platforms, making it a promising solution for the future of educational data management.

Keywords - Blockchain in education, decentralized data management, Ethereum, smart contracts, Web3, educational credential sharing, student-owned data, learning management systems (LMS), educational data security.

I. Introduction

The educational landscape is undergoing a major shift, driven by the rapid evolution of digital technologies, globalization, and the rise of new industries under Industry 4.0. As societies become increasingly digital, the way people learn and upskill is also transforming. The global pandemic further pushed this transition, highlighting the importance of online and remote learning. Many individuals were compelled to adapt, acquire new digital skills, and explore alternative learning paths outside traditional classrooms.

Alongside this shift, global initiatives such as Erasmus+ and DAAD have made it easier for students to participate in exchange programs and joint academic ventures. However, with students accessing courses from various sources and institutions, one persistent challenge remains: managing and transferring academic records across platforms. Learners often find it difficult to maintain a unified record of their achievements, especially when moving between countries or institutions.

This issue becomes even more critical in emergency situations. For example, students displaced by conflicts—like those from Ukraine—often lack formal documentation of their educational background. Without a centralized or verifiable source of truth, host institutions are forced to conduct interviews or additional exams to assess students' knowledge levels. These scenarios expose serious gaps in the current system of educational data management.

At present, educational data is largely controlled by institutions and government bodies. While this centralized model ensures some consistency, it falls short in flexibility, transparency, and student autonomy. Furthermore, the rise of private e-learning platforms and certification providers has led to an explosion of digital credentials that are not easily transferable or verifiable across systems.

A growing number of researchers have pointed to blockchain as a promising solution. Blockchain's core features—such as immutability, decentralization, and cryptographic security—make it a strong candidate for educational data storage and verification. Unlike traditional systems, blockchain enables peer-to-peer data sharing without relying on a central authority. This makes it well-suited for maintaining permanent, tamper-proof academic records.

Several studies have explored the application of blockchain in education, particularly for issuing certificates, managing digital badges, and verifying achievements. These works highlight the potential for increased trust, fraud prevention, and improved collaboration among institutions. However, most existing implementations still follow a top-down approach where institutions control the data—even if it's stored on a blockchain.

This paper takes a different approach. It argues that true decentralization can only be achieved if students themselves own and control their academic data. To support this, we introduce **DecentralEduChain**, a blockchain-based framework that allows students to store, manage, and share their educational records using smart contracts on the Ethereum public network.

What makes this framework unique is its alignment with the principles of Web3—a new wave of internet technologies focused on decentralization, digital identity, and user ownership. Web3 empowers individuals to manage their own data and interact with **decentralized applications (dApps**) using blockchain wallets. Through this system, students can securely store their records and authorize educational institutions to access or update them via Learning Management Systems (LMS) integrated with blockchain functionality.

I. Key contributions of this research include:

- A shift in perspective: Instead of giving institutions control over student data, this framework empowers students to be the rightful owners and custodians of their academic records.
- A complete, working model: The paper presents a hands-on framework built on Ethereum, including examples of smart contract deployment, LMS integration, and real data interaction.
- Practical insights into cost: Since public blockchains like Ethereum require gas fees to operate, the study provides transparent calculations to help future developers understand the financial implications of deploying such a system.

By proposing this decentralized approach to educational data management, the paper aims to lay the groundwork for a more student-centric, secure, and future-ready infrastructure that can support lifelong learning across borders and platforms.

II. Literature Review

A. Blockchain Technology and Its Educational Applications

Blockchain emerged in 2008 through a whitepaper published under the pseudonym Satoshi Nakamoto. Initially introduced as the foundation for cryptocurrencies, blockchain has evolved into a broader digital infrastructure that enables secure, decentralized data management across multiple sectors.

At its core, blockchain is a distributed ledger system where data is stored in cryptographically linked blocks and shared across a peer-to-peer network. Every transaction is validated by consensus mechanisms, ensuring trust without requiring a central authority. Scholars have emphasized different aspects of blockchain's potential—Reyna et al. described it as a transparent, tamper-resistant storage system, while Johar et al. highlighted its role in resolving trust issues via cryptography. What distinguishes blockchain from traditional databases is the decentralized nature of recordkeeping, where all participants (nodes) maintain synchronized copies, increasing fault tolerance and data integrity.

Three types of blockchain systems have emerged based on their structure and access controls:

- **Public Blockchains** are completely open, allowing anyone to participate, verify transactions, and contribute to the ledger. This promotes transparency and decentralization but may lead to scalability challenges due to consensus overheads.
- **Private Blockchains** restrict access to known participants, typically within an organization. While offering greater control and efficiency, they sacrifice some transparency and decentralization.
- **Consortium Blockchains** are semi-decentralized systems managed by a group of pre-authorized entities. These networks balance openness and control, often used in scenarios requiring shared governance.

Among blockchain's most powerful innovations are **smart contracts**—automated, self-executing programs that operate on the blockchain when specific conditions are met. These contracts eliminate intermediaries, reduce costs, and enhance the speed and security of transactions. Their potential extends beyond finance, with applications in healthcare, logistics, public administration, and education.

Despite these strengths, blockchain adoption faces several technical hurdles. Public blockchains using Proof of Work, such as Bitcoin, consume significant amounts of energy. High hardware costs, including those for GPUs used in mining, pose economic barriers. Moreover, the transparency of blockchain—while generally a strength—raises privacy concerns, as transaction patterns may be analyzed to infer user identities.

In educational contexts, blockchain offers promising solutions for managing and verifying academic credentials. It supports secure storage of certificates, transcripts, and digital badges, making them verifiable and tamper-proof. By eliminating dependence on intermediaries, blockchain also restores control to students over their own academic data—an increasingly critical consideration in decentralized learning environments.

B. Blockchain Use Cases in Education

Various research studies and pilot projects have demonstrated blockchain's utility in transforming education systems:

EduCTX, developed by Turkanovic et al., allows institutions to record students' course credits on a blockchain network following the ECTS standard. This ensures that learners can track and share their achievements across multiple institutions.

Chen et al. proposed replacing traditional paper diplomas with blockchain-anchored digital certificates, offering secure and permanent document verification for employers and universities.

Shen and Xiao introduced a system for recording exam content and results on blockchain. Their approach maintains both transparency and student anonymity by using pseudonymous identifiers during verification.

UniverCert, created by Kistaubayev et al., runs on the Ethereum public blockchain to track student loans and records. Despite limitations like transaction latency and gas costs, the solution was found to be effective in pilot testing across Kazakhstan's higher education system.

Al-Zoubi et al. focused on remote laboratory systems. They built a blockchain-backed framework integrated with Moodle via MetaMask, enhancing the security and reliability of data shared across institutional boundaries.

Cerberus, presented by Tariq et al., digitizes the diploma issuance and verification process. A graduate receives a QR-coded blockchain link to their credential, which institutions and employers can scan for verification. This solution uses a private blockchain and grants access to verified institutions only.

Abdelsalam et al. addressed vulnerabilities in digital examinations. They developed a system where students use MetaMask to log into a Moodle-based LMS, take exams, and have their answers recorded directly onto the Ethereum blockchain. This adds transparency, prevents tampering, and supports decentralized assessment workflows.

These projects differ in blockchain types, cost models, and the level of decentralization. While private networks often require infrastructure and expert personnel, public networks like Ethereum operate without dedicated hardware but incur transaction fees (gas). Some solutions emphasize institutional control, while others, such as **PublicEduChain**, align with Web3 ideals by placing ownership directly in students' hands.

C. Comparative Analysis and Research Gap

The reference framework, **PublicEduChain**, was compared with other leading blockchain-based educational solutions—such as EduCTX, UniverCert, and Cerberus—based on decentralization, transparency, LMS integration, cost structure, and data ownership.

Both **PublicEduChain** and **UniverCert** utilize Ethereum's public network, offering full decentralization and open accessibility. Other solutions based on private blockchains tend to limit transparency and require controlled access managed by select organizations.PublicEduChain distinguishes itself through student-centric data control. Students are responsible for creating their smart contracts, storing their academic records, and managing access permissions. In contrast, other platforms store data through institutional control, which limits user ownership.LMS integration is another key differentiator. Solutions like PublicEduChain, UniverCert, and the Online Exam Proposal offer blockchain integration with LMSs through APIs and browser-based tools like MetaMask. This integration is essential for seamless adoption in real academic environments.In terms of cost, private blockchains require infrastructure investments and maintenance by IT staff. Public blockchains shift this cost to individual users through transaction fees. PublicEduChain explicitly provides a breakdown of these gas fees, helping developers and institutions understand real-world financial implications.

Overall, ***PublicEduChain*** not only ensures decentralized, transparent, and verifiable academic data but also introduces a new paradigm where students, not institutions, are at the center of data ownership. This approach offers a scalable, affordable, and secure model for the future of educational data management.

TABLE 1: comparison

Solutions	**Blockchain Type**	**Decentralization/ Transparency**	**LMS Integration**	**Data Owner**	**Cost Detail**
Cerberus [50]	Private (Suitable for Ethereum, Quorum, Hyperledger)	Partially	No	Education Institution	No
UniverCert [1]	Public (Ethereum)	Yes	Yes	Education. Institution	Yes
EduCTX [47]	Private (Ark)	Partially	No	Education Institution	No
Proposal for Exam [51]	Private (Ethereum)	Partially	Yes	Education Institution	No
PublicEdu Chain	Public (Ethereum)	Yes	Yes	Student	Yes

III. Public Edu Chain Framework

The *PublicEduChain* framework presents a novel approach to educational data management by placing ownership and control directly in the hands of students. Leveraging the decentralized architecture of public blockchains—specifically Ethereum—this model eliminates the dependence on intermediaries such as academic institutions or certification bodies for data storage, access, and verification.

Ethereum was chosen as the foundational blockchain due to its maturity, wide adoption in academic and developer communities, and its alignment with Web3 principles. Unlike private blockchains, which often require specialized infrastructure and dedicated personnel, public blockchains like Ethereum offer a cost-effective, open-access platform where transactions are securely recorded and verified by a decentralized network.

One of the core reasons for opting for Ethereum is its ability to scale with the growing ecosystem of decentralized applications (dApps). This aligns well with Web3's vision of a user-owned internet, where identities and digital assets are controlled directly by individuals. With over 245 million active users and thousands of new smart contracts deployed daily, Ethereum is rapidly becoming the backbone of the decentralized web.

The *PublicEduChain* framework (illustrated in Figure1) enables students to create their own smart contracts, which serve as secure, personal data vaults on the Ethereum network. Learning Management Systems (LMSs) can integrate with these contracts, allowing institutions to both read and write authenticated records—such as certificates and grades—directly into the student-owned smart contract, using corporate Ethereum accounts. This setup simplifies processes like enrollment and academic verification, as students can log in with their blockchain IDs and manage their records independently.

The implementation of *PublicEduChain* involves several key components: creating smart contracts, integrating blockchain identities into LMSs, enabling data retrieval, and allowing authorized data submissions. These steps are described in the subsections below.

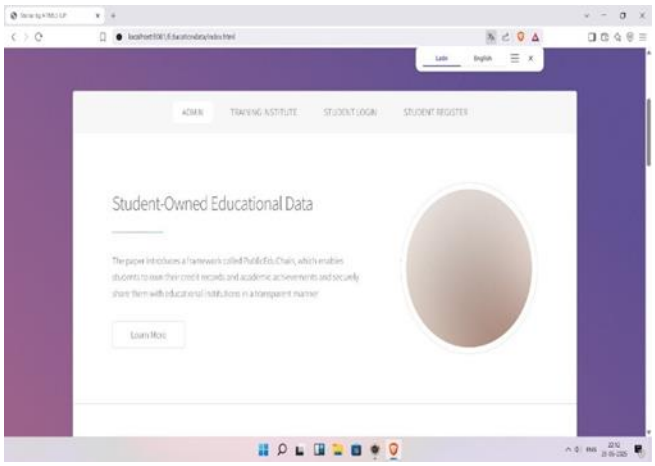
A. Student-Created Smart Contracts

The evolution of the internet toward Web3 has led to the rise of decentralized applications that offer user sovereignty and transparency. Tools like MetaMask and TrustWallet empower individuals to establish blockchain-based identities, which can serve as login credentials for various platforms—complementing or replacing traditional email or social logins.

In the context of education, this transformation enables students to independently manage their academic credentials. To support this, *PublicEduChain* proposes that students generate smart contracts—self-executing code on the blockchain that serves as their educational data repository.

Although creating smart contracts can be technically demanding, tools such as *MyWish* and *DappBuilder* simplify the process by offering prebuilt templates. These templates currently support use cases like token issuance and payments but are expected to expand to educational domains. Alternatively, platforms like *Remix* allow users to deploy customized smart contracts using the Solidity programming language, linked directly with their wallet applications.

In the PublicEduChain pilot implementation, a prototype smart contract was designed and deployed on the **Ethereum Sepolia Testnet**, using the **Remix IDE** in combination with the **MetaMask wallet extension**. This environment was chosen due to its developer-friendly interface and safe sandbox capabilities for testing decentralized applications without incurring real-world transaction costs. The smart contract was written in **Solidity**, Ethereum's native programming language, and includes a set of essential fields tailored for educational data management. These fields encompass the **Learning Management System (LMS) identifier**, **course title**, **type of credential** (e.g., certificate or grade), **description of the academic achievement**, and **date of issuance**. Together, these components form the foundational schema required to store and verify educational records in a decentralized, tamper-resistant manner.



B. Integrating Ethereum Identity with LMS

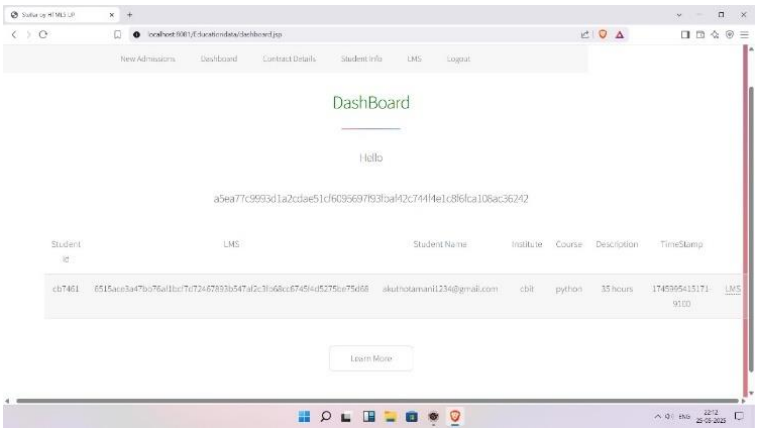
For real-world integration, the Moodle LMS was modified to support Ethereum-based login via MetaMask. This enables students to authenticate using their blockchain ID instead of traditional credentials. Backend modifications were carried out using PHP and MySQL through the XAMPP platform, and MetaMask login functionality was added using the open-source repository by Marountas.

After logging in, students can update their smart contract address in their Moodle profile, linking their LMS activity directly to their blockchain data store. This integration facilitates seamless access and management of educational records without creating new centralized user accounts.

C. Accessing Smart Contract Data from the LMS

To read the educational data stored in a student's smart contract, the Moodle LMS was enhanced with a PHP-based integration using a library created by Cabrera. Once a student has linked their contract address, authorized users (e.g., course instructors or admins) can retrieve stored records directly from the Ethereum network.

This retrieval is initiated via an added interface button, such as "Get Courses," on the student's LMS profile. By clicking this, LMS can securely query the student's contract and display previously recorded course data, certifications, or grades—providing transparency and continuity across institutions.



D. Writing Educational Records to Smart Contracts

Beyond retrieval, LMSs must also write new data—such as course completions or grades—to students' smart contracts. This requires an institutional Ethereum account capable of executing smart contract methods.

In the Moodle integration, a user with administrative permissions can input educational records through a custom interface. Once submitted, the data is recorded on the Ethereum blockchain and becomes publicly verifiable through services like Etherscan. For instance, if a student completes a course like "Data Science 102," the associated certificate and metadata are recorded in their contract via a blockchain transaction, timestamped and immutable.

This enables decentralized record-keeping where multiple LMSs can read/write to the same student contract, ensuring continuity and eliminating duplication of academic records across systems.

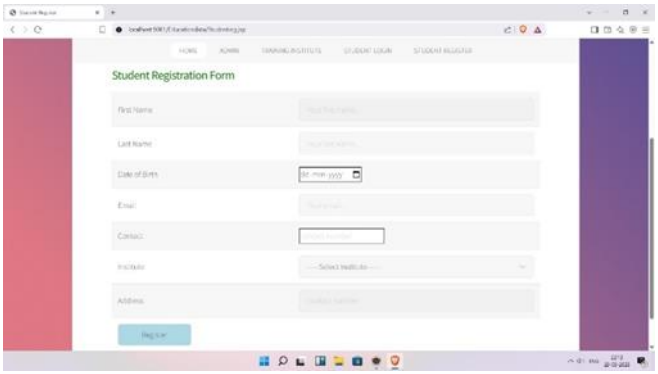
E. Cost and Sustainability of Public Blockchain Usage

Public blockchains operate on a fee-based model, where each transaction—such as writing to a smart contract—incurs a gas fee. This fee varies based on transaction complexity and current network congestion, calculated in gwei (a fraction of Ethereum).

In the *PublicEduChain* implementation, the cost of deploying a sample smart contract was approximately 13.61 USD, and writing an individual record cost about 2.3 USD, based on real-time exchange and gas rates. These minimal operational costs make Ethereum an attractive alternative to traditional infrastructure-heavy systems, which require dedicated servers, licenses, and ongoing IT support.

Since Ethereum transitioned to a Proof-of-Stake (PoS) consensus mechanism in 2022, energy usage has dropped by over 99%, enhancing its sustainability. Additionally, gas prices have stabilized, improving predictability for applications like *PublicEduChain*.

Overall, the financial model of paying small gas fees—without investing in infrastructure—makes Ethereum a cost-effective platform for decentralized educational data management.



IV. Technical Considerations and Integration Flexibility

Implementing the PublicEduChain framework required a range of software development skills, particularly in customizing the LMS and interacting with Ethereum's blockchain APIs. Throughout the development process, publicly available resources—including documentation, source code repositories, and community support forums—played a crucial role in overcoming integration challenges and building a functional prototype.

One of the key strengths of PublicEduChain is that it does not rely on proprietary hardware or licensed infrastructure. As a result, deploying the system in real-world educational settings is technically feasible with a small team of developers familiar with blockchain development and LMS integration. With the right expertise, institutions can set up and maintain the system with minimal operational overhead.

While Ethereum was chosen for this study due to its popularity, developer support, and alignment with Web3 standards, other public blockchain platforms such as **Neo** and **Qtum** also offer advanced features and could serve as viable alternatives. These platforms support rich development ecosystems, offering APIs in various programming languages, example projects, and active community engagement through forums and tutorials.

Moodle was selected as the Learning Management System for the proof-of-concept due to its open-source nature and wide usage in academic institutions. Since Moodle is built using PHP, the Ethereum integration was implemented using PHP-based libraries and APIs. However, this approach is not limited to PHP. Similar integrations can be developed in other programming languages, such as **Python**, which is used extensively in platforms like **edX**, an open-source education system supported by many universities worldwide.

This level of cross-platform interoperability opens doors for secure and transparent educational data exchange between different institutions. For example, a certificate written to a student's blockchain contract via a Moodle-based LMS could be accessed and verified by another institution running an edX-based platform—without compromising data ownership or privacy.

To fully realize the decentralized model of data ownership envisioned by PublicEduChain, students need the ability to create blockchain accounts and deploy smart contracts independently. In the prototype, this was demonstrated using MetaMask and Remix IDE—two tools that allow users to write and publish smart contracts with minimal technical setup. While most students today may not possess the skills to build smart contracts from scratch, it is expected that as Web3 adoption grows, user-friendly tools, templates, and guided interfaces will emerge to simplify this process. Over time, interacting with blockchain infrastructure may become as routine as managing email or cloud accounts today.

The test implementation of PublicEduChain was carried out on Ethereum's Sepolia Testnet—a sandbox environment used for development and experimentation. To estimate real-world applicability, the associated costs for smart contract deployment and data writing were also calculated on the Ethereum main network. Since public blockchains are maintained by decentralized participants, operational costs are supported through small fees (known as **gas fees**) applied to each transaction.

This implies that both students and institutions would need access to the native cryptocurrency of the blockchain they are operating on (e.g., ETH for Ethereum) to perform actions such as creating a contract or updating academic records. However, these fees remain relatively modest compared to the infrastructure and maintenance costs of centralized systems.

V. Limitations and Future Directions

While the PublicEduChain framework demonstrates significant promise in enabling decentralized management of educational data, it is important to recognize the limitations that come with deploying such systems on public blockchain networks. These limitations present opportunities for further research and development.

A. User Account Recovery and Decentralized Responsibility

Public blockchains like Ethereum operate without centralized oversight. As a result, there is no dedicated authority or support channel to assist users with common issues such as lost passwords, forgotten seed phrases, or account recovery. In PublicEduChain, students are required to use wallet applications

like **MetaMask** to access their Ethereum accounts. If a student misplaces their account credentials or fails to back up their private keys securely, there is no institutional mechanism to retrieve access—posing a significant barrier for non-technical users.

While decentralization offers resilience and autonomy, it also introduces challenges in user support and accountability. Addressing these usability gaps may require technical innovations or legal frameworks that define best practices for account recovery, identity verification, and user protection in blockchain-based educational systems.

B. Irreversibility of Blockchain Transactions

A fundamental property of blockchain technology is immutability—once a transaction is recorded, it cannot be altered or removed. Although this feature enhances trust and transparency, it poses a challenge when erroneous entries are made. For example, if a student or LMS administrator mistakenly submits incorrect data to a smart contract, there is no way to delete or overwrite the entry.

To mitigate this issue, the smart contract design in PublicEduChain can be extended to include an **"active/inactive" status field** for each data record. This would allow previously recorded data to be logically deactivated without deleting it, enabling systems to filter and reference only valid entries. This method preserves immutability while allowing for correction and error handling.

C. Cost of Blockchain Transactions

While Ethereum provides a robust and scalable infrastructure, it operates on a **gas fee model**, requiring cryptocurrency payments for each transaction. In PublicEduChain, students are expected to pay a one-time fee when creating their smart contracts, while LMS platforms incur fees for every data-writing operation. These costs fluctuate depending on network congestion and gas prices, which may impact the system's scalability and accessibility.

Educational institutions can consider offsetting these costs by absorbing them into operational budgets, offering student sponsorships, or leveraging third-party funding sources. Furthermore, LMSs can strategically schedule high-volume data submissions during periods of lower network activity to minimize total expenses. These financial dynamics highlight a need for more detailed cost-optimization studies in future work.

D. Data Validation and Institutional Verification

Another challenge is the potential for misuse or data manipulation. Since anyone can create a smart contract or write to an existing contract on the public Ethereum network, the system is open to potential abuse, such as unauthorized data submission or impersonation of institutions. Although the requirement to pay gas fees naturally deters spam and large-scale attacks, the risk of isolated abuse remains.

To strengthen trust, educational institutions can publicly list their **official Ethereum addresses** on their websites, email signatures, or social media accounts. This enables students, employers, and other institutions to verify the legitimacy of records based on the sender's blockchain identity. Including the verified address in the **"LMSAddress"** field of each contract record further enhances transparency and accountability.

Looking ahead, a structured verification protocol or decentralized registry of approved educational institutions could help ensure that only legitimate entities are authorized to issue academic records. This would support broader adoption and interoperability across academic networks.

E. Future Research Opportunities

The limitations identified in this study point to several directions for future research:

Developing user-friendly tools for smart contract creation, tailored specifically for non-technical users like students. Investigating hybrid models that combine decentralized storage with centralized support layers for account recovery and identity verification.

Exploring dynamic fee optimization algorithms that adjust transaction schedules based on real-time gas prices. Establishing decentralized identity frameworks or reputation systems to validate institutional participation in educational blockchain ecosystems.

By addressing these areas, future iterations of PublicEduChain—or similar decentralized learning infrastructures—can become more practical, secure, and inclusive for global academic communities.

VI. CONCLUSION

The secure and efficient management of educational records remains a significant challenge, particularly in environments vulnerable to crises such as war, political instability, or natural disasters. In traditional systems, educational data is centrally controlled by institutions, limiting interoperability, ownership, and resilience. Moreover, the growing number of private educational providers offering certification and lifelong learning programs are often excluded from institutional data-sharing networks, creating further fragmentation.

This research addresses a critical gap in existing literature by introducing **PublicEduChain**—a decentralized framework that empowers students to take ownership of their academic data. Unlike conventional models, where institutions govern data storage and access, PublicEduChain leverages blockchain technology to allow students to store and share their credentials independently, without relying on any centralized authority.

By utilizing the **public Ethereum network**, the framework ensures a high level of decentralization and transparency while avoiding infrastructure costs typically associated with private or consortium blockchain setups. This approach aligns closely with the ethos of **Web3**, which envisions a more democratic and trustless internet where individuals—not platforms—control their data and identity.

The study not only proposes the conceptual architecture of PublicEduChain but also presents a detailed implementation using Moodle as a case study. It explains the integration process, highlights the tools used (such as MetaMask and Remix), and demonstrates how smart contracts can be deployed and managed by students and institutions alike. Each step is supported by visuals and code references, making this work a practical guide for future researchers and developers.

One of the key contributions of this study lies in its **real-world cost evaluation**. By simulating the smart contract deployment and transaction process on the Ethereum test network, the study provides insight into the actual gas fees and financial feasibility of adopting public blockchains for education. This information, often lacking in theoretical research, adds pragmatic value to the academic discourse.

Looking ahead, the rapid evolution of **information and communication technologies**—including smart contracts, decentralized identity systems, NFTs, and the Metaverse—signals a major shift toward user-centric and decentralized applications. As trust becomes a core currency in digital ecosystems, it is expected that users will increasingly gravitate toward systems that minimize reliance on intermediaries.

PublicEduChain represents a forward-thinking response to this shift. While current limitations, such as the technical barrier for students to create smart contracts or integrate LMS platforms, may hinder immediate adoption, these challenges are likely to diminish as Web3 tools become more accessible and user-friendly.

In conclusion, PublicEduChain lays the foundation for a new paradigm in educational data ownership and interoperability. It offers a scalable, secure, and student-focused model that can redefine how academic records are created, accessed, and shared in the digital age. With continued development and community engagement, this framework has the potential to become a cornerstone of decentralized education in the years to come.

REFERENCES

[1] Y. Kistaubayev, G. Mutanov, M. Mansurova, Z. Saxenbayeva, and Y. Shakan, "Ethereum-based information system for digital higher education registry and verification of student achievement documents," *Future Internet*, vol. 15, no. 1, p. 3, Dec. 2022, doi: 10.3390/fi15010003.

[2] Erasmus+, "Opportunities for individuals: Erasmus Mundus Joint Masters." [Online]. Available: https://erasmusplus.ec.europa.eu/opportunities/opportunities-for-individuals/students/erasmus-mundus-joint-masters. Accessed: Sep. 5, 2023.

[3] DAAD – Germany, "Study and research in Germany." [Online]. Available: https://www.daad.de/en/study-and-research-in-germany/. Accessed: Sep. 5, 2023.

[4] M. Rataj and I. Berezovska, "Addressing challenges with Ukrainian refugees through sustainable integration: Response of the educational community in Poland," *J. Further Higher Educ.*, vol. 47, no. 9, p. 1227, Oct. 2023, doi: 10.1080/0309877x.2023.2241386.

[5] A. Alammary, S. Alhazmi, M. Almasri, and S. Gillani, "Blockchain-based applications in education: A systematic review," *Appl. Sci.*, vol. 9, no. 12, p. 2400, Jun. 2019, doi: 10.3390/app9122400.

[6] F. Loukil, M. Abed, and K. Boukadi, "Blockchain adoption in education: A systematic literature review," *Educ. Inf. Technol.*, vol. 26, no. 5, pp. 5779–5797, Sep. 2021, doi: 10.1007/s10639-021-10481-8.

[7] P. Bhaskar, C. K. Tiwari, and A. Joshi, "Blockchain in education management: Present and future applications," *Interact. Technol. Smart Educ.*, vol. 18, no. 1, pp. 1–17, 2020, doi: 10.1108/ITSE-07-2020-0102.

[8] A. F. Camilleri, A. I. dos Santos, and A. Grech, "Blockchain in education," *Eur. Commission Joint Res. Centre*, Seville, Spain, 2017, doi: 10.2760/60649.

[9] A. Mohammad and S. Vargas, "Barriers affecting higher education institutions' adoption of blockchain technology: A qualitative study," *Informatics*, vol. 9, no. 3, p. 64, Aug. 2022, doi: 10.3390/informatics9030064.

[10] J. Bambacht and J. Pouwelse, "Web3: A decentralized societal infrastructure for identity, trust, money and data," *arXiv preprint*, arXiv:2203.00398, 2022.

[11] Ethereum Name Service, "ENS Domains." [Online]. Available: https://ens.domains/tr/. Accessed: Sep. 11, 2023.

[12] S. Johar, N. Ahmad, W. Asher, H. Cruickshank, and A. Durrani, "Research and applied perspective to blockchain technology: A comprehensive survey," *Appl. Sci.*, vol. 11, no. 14, p. 6252, Jul. 2021, doi: 10.3390/app11146252.

[13] A. Lewis, "So, you want to use a blockchain for that?" *CoinDesk*. [Online]. Available: https://www.coindesk.com/want-use-blockchain/. Accessed: Nov. 9, 2018.

[14] V. Gatteschi, F. Lamberti, C. Demartini, C. Pranteda, and V. Santamaria, "To blockchain or not to blockchain: That is the question," *IT Prof.*, vol. 20, no. 2, pp. 62–74, Mar. 2018, doi: 10.1109/MITP.2018.021921652.

[15] L. Luu, D.-H. Chu, H. Olickel, P. Saxena, and A. Hobor, "Making smart contracts smarter," in *Proc. ACM SIGSAC Conf. Comput. Commun. Secur.*, New York, NY, USA: ACM Press, 2016, pp. 254–269, doi: 10.1145/2976749.2978309.

[16] T. Savelyeva and J. Park, "Blockchain technology for sustainable education," *Br. J. Educ. Technol.*, vol. 53, no. 6, pp. 1591–1604, Nov. 2022, doi: 10.1111/bjet.13273.

[17] K. Burgess, "The promise of Bitcoin and the blockchain," *Consumers' Res. Primary*. [Online]. Available: https://www.academia.edu/23117440/The_Promise_of_Bitcoin_and_the_Blockchain_A_product_of. Accessed: Nov. 12, 2018.

[18] M. Swan, *Blockchain: Blueprint for a New Economy*. Sebastopol, CA, USA: O'Reilly Media, 2015.

[19] J. L. Zhao, S. Fan, and J. Yan, "Overview of business innovations and research opportunities in blockchain and introduction to the special issue," *Financial Innov.*, vol. 2, no. 1, p. 28, Dec. 2016, doi: 10.1186/s40854-016-0049-2.

[20] A. Kamišalić, M. Turkanović, S. Mrdović, and M. Heričko, "A preliminary review of blockchain-based solutions in higher education," in *Learning Technology for Education Challenges*, Zamora, Spain: Springer, 2019, pp. 114–124, doi: 10.1007/978-3-030-20798-4_11.

[21] J. Nespor, "Cyber schooling and the accumulation of school time," *Pedagogy, Culture Soc.*, vol. 27, no. 3, pp. 325–341, Jul. 2018, doi: 10.1080/14681366.2018.1489888.

[22] M. Turkanovic, M. Hölbl, K. Kosic, M. Hericko, and A. Kamisalic, "EduCTX: A blockchain-based higher education credit platform," *IEEE Access*, vol. 6, pp. 5112–5127, 2018, doi: 10.1109/ACCESS.2018.2789929.

[23] H. Shen and Y. Xiao, "Research on online quiz scheme based on double layer consortium blockchain," in *Proc. 9th Int. Conf. Inf. Technol. Med. Educ. (ITME)*, Oct. 2018, pp. 956–960, doi: 10.1109/ITME.2018.00213.

[24] A. Y. Al-Zoubi, M. Dmour, and R. Aldmour, "Blockchain as a learning management system for laboratories 4.0," *Int. J. Online Biomed. Eng.*, vol. 18, no. 12, pp. 16–34, Sep. 2022, doi: 10.3991/ijoe.v18i12.33515.

[25] Qtum, "Qtum blockchain platform." [Online]. Available: https://qtum.org/. Accessed: Sep. 25, 2023.