Journal of Applied Sciences, Information and Computing
Volume 6, Issue 2, Nov - Dec 2025
School of Mathematics and Computing, Kampala International University

ISSN: 3007-8903 https://doi.org/10.59568/JASIC-2025-6-2-09

An Academic Transcript System based on a Modified Blockchain Architecture

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Abstract

Blockchain technology has emerged as a transformative innovation in secure and decentralized data management. Initially developed for cryptocurrencies, it has expanded into various industries, including academic record management. Its immutable and decentralized structure makes it ideal for preserving the integrity, security, and authenticity of sensitive records. Traditional transcript systems are prone to tampering, unauthorized modifications, and inefficient verification processes. This study developed a blockchain-based academic transcript system aimed at enhancing security, transparency, and efficiency. The system integrates optimized smart contracts and consensus mechanisms within a modified blockchain framework to automate transcript issuance and verification. By utilizing blockchain's immutable ledger, it ensures verifiable, tamper-proof academic records, reducing the risks of fraud and data breaches. JSON Web Tokens (JWT) were employed in the back end for secure data exchange between the application and the Ethereum blockchain, removing vulnerabilities from third-party authentication tools. The back end was built using PHP (Laravel), while HTML, CSS, and JavaScript were used for the front end. An on-chain explorer module was added to the front end, enabling institutions and employers to verify transcripts easily. Results indicate that the system effectively supports academic transcript applications and verification, achieving a system efficiency of 95.2%. User evaluation showed notable improvements in security, performance, and satisfaction, confirming blockchain's potential in academic record management. The system not only improves trust and transparency in credentialing but also lays the groundwork for innovative practices in the education sector.

Keywords: Academic Transcript System, Blockchain Technology, Ethereum, JWT, On-chain Explorer, Server

1. Introduction

The management of academic transcript records in the educational sector has traditionally relied on centralized systems, which are susceptible to issues such as data tampering, loss, and unauthorized access (Grech & Camilleri, 2017). These challenges underscore the need for a more secure and efficient approach to handling academic credentials. Blockchain technology offers a promising solution by providing an immutable and transparent framework for recording and verifying academic achievements. By leveraging blockchain, institutions can ensure that academic records are securely stored and easily verifiable, thereby enhancing trust and reducing fraud in credentialing processes (Turkanovic, 2019).

The implementation of blockchain in academic settings is not without challenges. Scalability is one such challenge, as the current infrastructure of many educational

institutions may not be equipped to handle the widespread adoption of blockchain technology. Furthermore, blockchain networks can be resource-intensive, requiring significant computing power and storage capacity. Educational institutions may need to invest in upgrading their technological infrastructure to fully realize the benefits of blockchain-based record management systems (Alammary et al., 2019).

The blockchain technology, first developed for cryptocurrency systems, offers a viable solution to current problems through its transparent, decentralized, and tamper-resistant design. Its effectiveness in securely documenting and verifying transactions over a distributed network makes blockchain to be highly suitable for enhancing the security and efficiency of academic record management (Arndt et al., 2022).

The transparency and immutability that comes with blockchain technology also provide a level of trust that traditional systems lack. Blockchain based system has the potential to protect academic records from manipulation, ensuring that both institutions and employers can trust the credentials being presented. Additionally, it ensures safeguarding records from cyber-attacks or accidental loss due to system failures (Alammary et al., 2019).

Incorporating blockchain into academic transcript systems ensures that once the transcript is added, it cannot be altered without the consensus of the network. This creates a high level of security and trust. Its cryptographic design makes it ideal for preventing unauthorized changes, making it an excellent tool for maintaining academic integrity (Grech & Camilleri, 2017). Lemieux (2016) argues that blockchain can provide a trusted, transparent, and secure platform for maintaining academic records.

This paper presents the design and implementation of a blockchain-based academic transcript system that uses the Ethereum blockchain and the security features of JSON Web Tokens (JWT) to ensure secure data exchange between the application and the blockchain.

Additionally, the system also includes a tamper-proof on-chain verification tool, enabling institutions and employers to quickly and confidently verify the authenticity of academic records. This solution addresses common issues such as transcript tampering and unauthorized modifications, especially in regions with less reliable verification processes.

2. Literature Review

This section reviews existing literature on transcript management systems, key concepts and features of blockchain technology, and its architectural framework. It also reviews current research on how blockchain is being integrated into educational settings. In addition, case studies and pilot projects are examined to highlight both the potential benefits and the challenges of using blockchain for academic transcript systems.

According to Rajesh & Babu (2019) addressed security vulnerabilities in traditional academic record systems. By implementing a secure blockchain-based academic record system with encryption, they improved the security and tamper-proofing of academic records. Their methodology offers a significant advancement in protecting academic data. Nonetheless, the system's scalability issues and resource-intensive implementation remain critical limitations, which could affect its broader application. Daraghmi et al., (2019) addressed the inefficiencies and privacy issues in data sharing caused by unconnected existing systems. They developed UniChain using time-based smart contracts and advanced encryption techniques to secure access to academic records. Their methodology improves interoperability and privacy in managing academic records, making it easier for various stakeholders to share and access data securely. However, the complexity of implementation and high resource requirements pose significant challenges, potentially limiting the system's widespread adoption.

However, Thanh-Tung et al. (2020) tackles the challenge of verifying academic credentials while maintaining privacy. By implementing a blockchain-based system with selective disclosure capabilities, they enhanced both the privacy and verifiability of academic credentials. Their achievement lies in providing a secure and private method for credential verification. Nevertheless, the system faces limitations in terms of adoption and integration challenges with existing educational infrastructures, which may hinder its practical deployment. Pham & Hoang (2020) developed a blockchain-based system to facilitate cross-border verification of academic degrees, thereby reducing fraud and administrative burdens. Their contribution lies in streamlining the verification process and enhancing the reliability of academic credentials. However, they face regulatory challenges in different countries, which could impede the system's global implementation. Arndt & Guercio (2023) explored the challenges faced by mobile students in higher education due to administrative delays and inefficiencies by implementing blockchain technology and smart contracts to streamline and secure the management of academic transcripts. This approach aimed to reduce friction and delays in administrative processes, thus better supporting mobile students. However, the study acknowledged the initial complexity of implementation and the need for widespread adoption across institutions to realize its full potential. Malsa et al. (2023) proposed a scalable framework utilizing blockchain and smart contracts, enhanced by robotics for automation. This system aimed to improve the security and efficiency of certificate verification processes in academic institutions. Despite its potential benefits, the study noted that high costs and technical complexity could pose significant barriers to implementation.

Al Harthy et al., (2023) investigated the lack of standardized processes for blockchain adoption in higher education and identified the essential requirements and processes needed for effective blockchain adoption in higher education institutions. They provided a valuable roadmap for institutions looking to integrate blockchain technology. However, they noted that there is limited empirical data on the long-term outcomes of blockchain adoption in this context. Rustemi et al., (2023) provides a comprehensive overview of the current state and future potential of blockchain technology in the educational sector, particularly in the verification of academic credentials. They highlighted significant contributions

from researchers, identifies major themes and research gaps, and offers recommendations for future research and practical applications. As blockchain technology continues to evolve, its impact on education is expected to grow, offering new opportunities for innovation and improvement in academic credential verification.

Ishak & Harun (2023) approach involved combining two blockchain, Polygon Testnet Faucet and Ethereum, and incorporating QR codes for verifying transcripts. they highlighted a significant vulnerability in QR code usage in blockchain which could lead to data breaches and unauthorized access to sensitive information, and also, highlighted that some older smartphone may not have a built-in QR code reader, there by recommending adopting only the Ethereum blockchain in other to enhance the system efficiency and reduce complexity. Putri et al., (2024) addressed the inefficiencies and security issues in traditional diploma and transcript verification systems. By implementing a blockchain-based solution on the Ethereum network, the study enhances the security, transparency, and efficiency of the verification process. Despite its advantages, the method presents challenges such as high costs and technical complexity. This research offers significant contributions to the field of academic credential verification.

2.1 Research Gap

The study by Ishak & Harun (2023) highlighted significant advancements in security, transparency, and verification. However, they identified several flaws in implementing their Trusted Transcript Management System Using Blockchain. One key issue was the reliance on the Polygon Testnet Faucet combined with the Ethereum blockchain, which they recommended the use of only Ethereum for integrating blockchain technology into existing transcript systems. Additionally, a significant limitation of their implementation was the use of a QR code verification module, which is not dependable for validating transcript records and ensuring trust among stakeholders. Despite these limitations, their system achieved an overall performance rating of 85.7%, indicating significant potential but leaving room for further improvements.

This research builds upon their findings with a more streamlined and user-friendly blockchain-based academic transcript system that enhances security, efficiency, and reliability. This study leverages JSON Web Tokens (JWT) in the back-end for secure data exchange between the application and the Ethereum blockchain, eliminating vulnerabilities associated with third-party authentication tools. Additionally, the system introduces a tamper-proof on-chain verification module in the front-end, allowing educational institutions and employers to authenticate academic transcripts seamlessly.

3. Methodology

To effectively meet the research objectives, Scrum, a type of agile software development methodology was adopted and used. Scrum methodology was adopted because of its flexible and iterative approach that focuses on delivering components and functional parts of a project through continuous collaboration between cross-functional individuals and teams. Unlike traditional models, such as the Waterfall method, which follow a linear and rigid progression, scrum breaks down development into time-boxed iterations during which developers focus on delivering functional product increments. (Schwaber and Sutherland, 2017).

To meet the system requirements, the blockchain-based academic transcript processing system was designed, which employs a multi-tiered architecture, consisting of the frontend, backend, database, and blockchain layers, each with distinct roles contributing to a cohesive user experience showed below in figure 1.

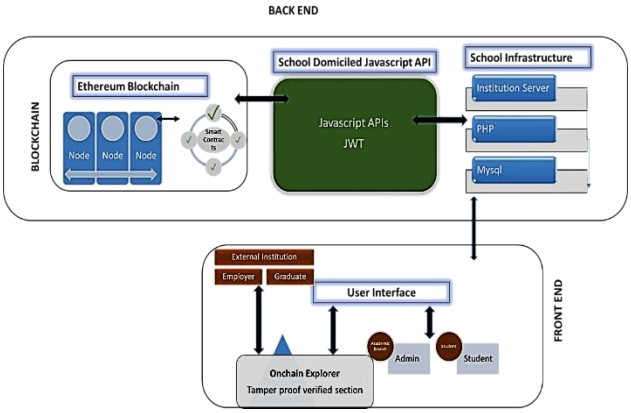

Figure 1; A Modified Blockchain based academic transcript system architecture

3.1 System Components

Json Web Token: this JWT streamlines authentication, improves transaction efficiency, and strengthens data confidentiality in academic transcript Blockchain Implementation.

User Interface: This is the interface where all users can register and login, the admin, students and institutional staff can see all the features of the system they can use.

Node: A blockchain node refers to a device-stakeholder pair that participates in running the protocol software of a decentralized network.

Smart-contract: A smart contract is a technique for digitally validating contract agreements.

Blockchain Layer: Deployed on the Ethereum blockchain, this layer uses smart contract to securely handle transcript processing fee payments, ensuring transaction integrity.

Backend Layer: This is the component of the system responsible for sending admin/users request to the blockchain and also sends the blockchain response to the system user.

Frontend Layer: provides an intuitive user interface for both students and system admin interactions. It enables students and administrators to request transcripts and access various features seamlessly

Onchain Explorer: it enables the tracking of blockchain activities and transactions, viewing of wallet balances, and monitoring of network activity, thereby enhancing transparency and trust within the blockchain ecosystem.

School infrastructure: this is where all the student information is securely stored within the institution database.

3.2 Use Case Diagram

The use case diagram, showed in Figure 2, illustrates how each user interacts with the system, outlining their roles, responsibilities, and the conditions required for successfully completing specific tasks. Each users reflects a specific part of the system, such as student, admin, and institution board, defining their responsibilities and behaviors associated with those components.

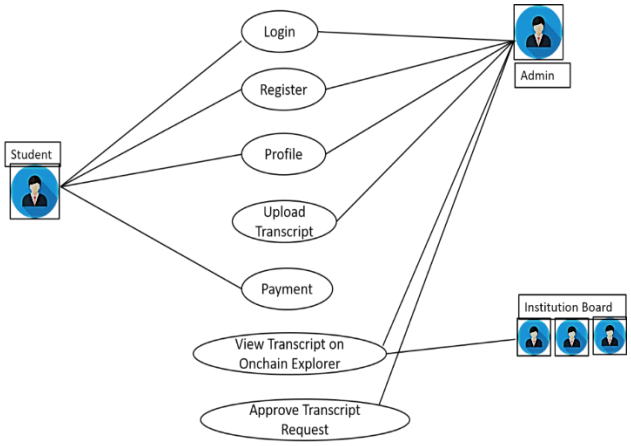

Figure 2: Use case diagram showing how user interacts with the system.

3.3 System Flow Chart

The flow chart for the blockchain-based academic transcript system is illustrated in Figure 3 This chart visually represents the various processes involved, outlining the sequence of steps necessary for generating and managing academic transcripts securely. It highlights key interactions between users and the system, including data input, verification, and the issuance of transcripts. By mapping these processes, the flow chart serves as a useful tool for understanding the workflow and ensuring efficient operation within the blockchain framework.

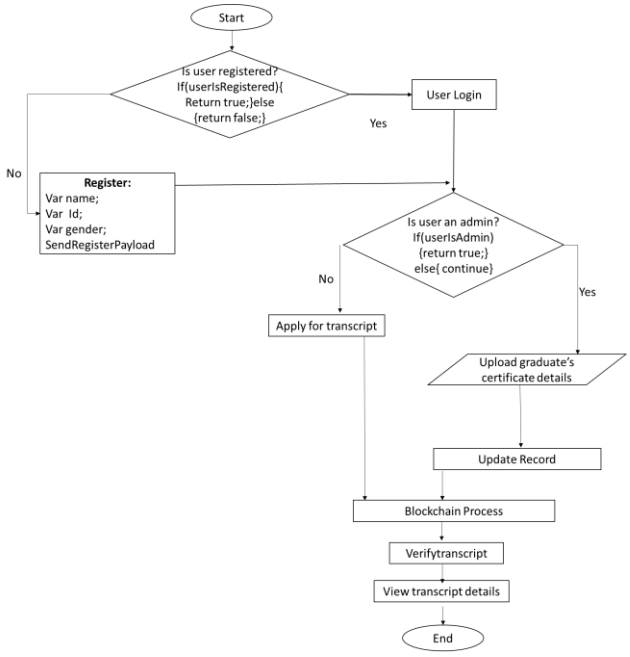

Figure 3: System Flow Chart for the blockchain based academic transcript System

3.4 System Requirement analysis

The following are the system requirements.

3.5.1 Functional Requirements

- A new user must register before they can access the transcript as a registered user can.
- A new user must fill out a form with fields for his or her name, address, phone number, gender, email, age, user id, and password.
- The system will request user confirmation after receiving all the information.
- The system must authenticate users securely, ensuring that only authorized users can access specific resources.
- The system must manage user permissions to access and apply for transcript.
- The user must supply the requested information in order to cancel the request

3.5.2 Non-Functional Requirements

- **Performance:** The system must be quick and reliable to process request.
- **Scalability:** The system must be able to handle a large number of transactions and a growing number of users.
- **Security:** The confidential Information is only visible to only one authorized person. The administrator is the only one with access to the user's information.
- **Usability:** The system must offer a user-friendly interface for users.

3.5.3 Hardware Requirements

- Fast Processor: A high-performance processor capable of meeting the demanding computational needs of a blockchain network.
- Server: A reliable computer or server capable of running the required software smoothly.
- RAM: Sufficient Random Access Memory (RAM) is provided to support smooth data processing and system performance.
- Fast Processor: A powerful processor to handle the computational requirements of the blockchain network.
- Large Storage Capacity: Sufficient hard disk space to store the blockchain data and associated files.

3.5.4 Software Requirements

- Operating System: Windows (e.g., Windows 10, Windows 11) as the preferred operating system for hosting the software stack.
- Mysql: Utilize Mysql, a SQL database, to store additional non-blockchain related data and facilitate seamless integration with blockchain.
- Laravel: It allows the development of the back-end of the library system.
- Visual Studio Code: Use Visual Studio Code as the integrated development environment (IDE) for coding and project management.

https://doi.org/10.59568/JASIC-2025-6-2-09 JASIC 6(2), 70-76

- HTML, CSS, and JavaScript: Use these front-end technologies to create the user interface and enhance the user experience.

3.5 Program documentation

The following steps must be taken for the system to function on any computer system:

- Start the computer.
- Set up XAMP on your server.
- Activate the server.
- Launch any browser that is installed on the computer, such as Netscape Navigator, Opera, Mozilla Firefox, Flock, Safari, and Microsoft Internet Explorer.
- In the address bar, type http://127.0.0.1:8000 then hit the return or enter keys.
- The students and system admin can use the same login interface.
- View the institution transaction history by typing http://127.0.0.1:8000/onchainExplorer.

4. Results

4.1 System Result output Home Page

The homepage is the main entry point for both users and admins, providing access to sections like About, Admin, and User areas. It serves as an authorized and authenticated interface, as shown in Figure 4.

Figure 4: Screenshot for Homepage

4.1.2 Admin/User Login

For the admin login, the administrator/user can securely access the system using a unique username and password. as shown in Figure 5.

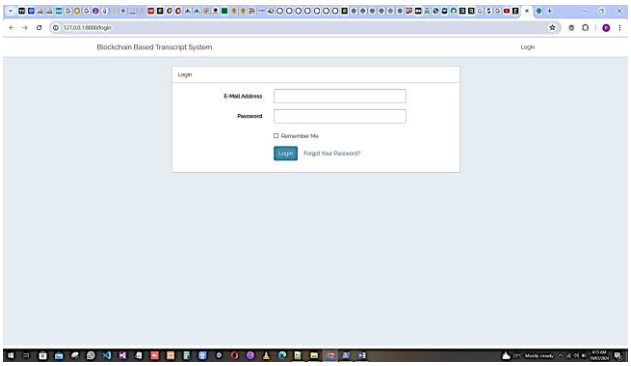

Figure 5: Screenshot for admin/user login

4.1.3 Admin Generate Verification code

In this section, Figure 6 demonstrates how the admin generates a unique code that can be used to verify the authenticity of a student's transcript. When this code is entered into the on-chain explorer, the transcript becomes accessible for viewing or download. However, the admin retains control of the code. If an institution or organization requires access to a student's transcript, the admin can share the code with them, enabling secure and verifiable confirmation of the transcript's authenticity.

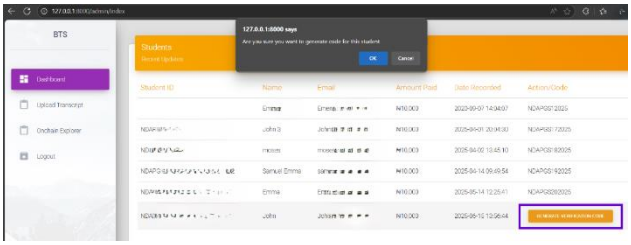

Figure 6: Screenshot of admin generating verification code

4.1.4 Admin/User Onchain Explorer

In this section, Figure 7 displays the on-chain explorer section, where both the admin and institutions can easily verify the authenticity of a academic transcript by entering the verification code generated in Figure 6.

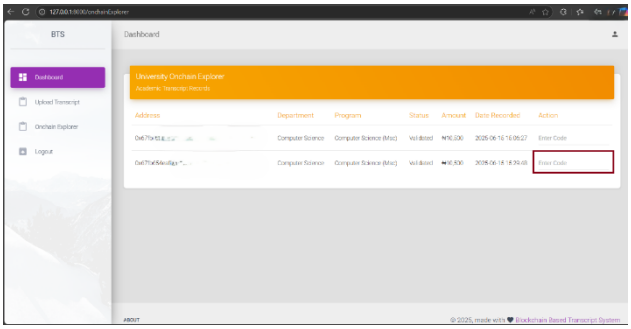

Figure 7: Screenshot for admin/user onchain explorer

4.1.5 JWT action with transcript application

In this section, Figure 11 illustrates the action of JWT during transcript application, enabling secure authentication and data transmission between the transcript management system and the blockchain network via MetaMask, allowing users to establish a trusted connection with the blockchain without constantly re-entering credentials.

When a user logs in to request a transcript, the system generates a JWT containing their credentials, which is then used to authenticate the user's identity and facilitate interaction with the smart contract on the Ethereum blockchain. This security measure prevents unauthorized access and ensures that only verified users can initiate transcript processing or verification.

Furthermore, JWT enhances data integrity and security by ensuring that only authenticated transactions are recorded on the blockchain. Once a user requests a transcript, the application validates the JWT before interacting with

MetaMask, which acts as a digital wallet for managing blockchain transactions. This secure authentication mechanism mitigates risks associated with unauthorized access and ensures that only legitimate users can process and verify transcript records.

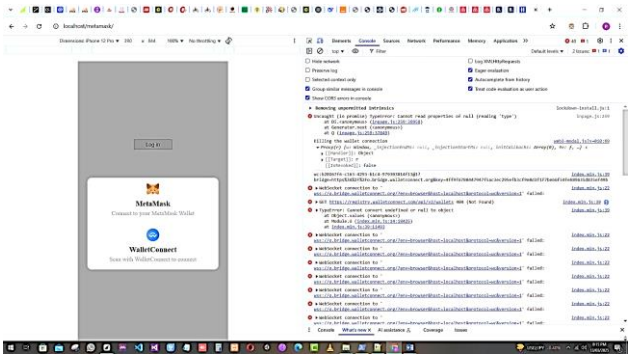

Figure 8: Screenshot of JWT Action with transcript application when is in use.

4.2 System User Acceptance Testing

A User Acceptance testing was used to evaluate the test cases of the system by diverse user groups, targeting Blockchain users, students, staff and institution employees. A structured User Acceptance Testing (UAT) questionnaire was distributed, utilizing a 7-point Likert scale ranging (Very Dissatisfied 1 - 7 very Satisfied). The scale assessed user satisfaction across key parameters such as system usability, ease of use, and overall user experience where:

1 = Very dissatisfied
2 = Moderately dissatisfied
3 = Slightly dissatisfied
4 = Neutral
5 = Slightly satisfied
6 = Moderately satisfied
7 = Very satisfied

User feedback was gathered from both groups through a survey conducted after they had used the system, the results of the user acceptance survey are presented in table 1. To facilitate easy access the survey was conducted based on practical usage and user acceptance form.

Table 1: User acceptance survey

Feature Domain/SN	Evaluation Criteria	Feedback Score
User Registration		
1	Seamless user registration process	7
2	System provides clear error messages	6
Login Functionality		
3	Successful user login without issues	7
4	Informative error messages on login failure	6
Admin/student Control Features		
5	Student can view profile information	6
6	Admin can successfully upload transcript	7
7	Admin can manage transcript	7
Transcript Application		
8	Students can apply for transcript	7
9	Users can pay for transcript	7
10	Results can be verified via onchain explorer	7
Overall System Performance		
11	Users can navigate and utilize the system effectively	6
12	The interface is intuitive and user-friendly	7
13	The system is easy to operate	7

5. Discussion

The study reveals that the academic transcript system demonstrated superior performance in user authentication, transcript management, payment processing, and verification accuracy, leading to an overall system efficiency rating of 95%, compared to 85.7% in the benchmark system showed in table 1. The transition from QR code verification to an on-chain explorer played a crucial role in enhancing trust and security in academic transcript validation. Also, by leveraging the security features of JWT, the system will ensure secure authentication and data transmission between the transcript management system and the blockchain network, allowing users to establish a trusted connection with the blockchain without constantly re-entering credentials. While our system excels in several areas, improvements in error feedback mechanisms and navigation refinement could further enhance user satisfaction. These findings reinforce the importance of blockchain technology in academic record management, highlighting its potential to improve security, transparency, and system reliability over traditional approaches.

6. Conclusion

This study has presented the design and implementation of an academic transcript system and also combined strengths of an Ethereum blockchain technology with JWT to enhance the security, efficiency, transparency, and institutional collaboration. The immutable nature of blockchain ensures tamper-proof storage of academic records, eliminating the risks of fraud and unauthorized

modifications. By integrating smart contracts, the system automates administrative processes, reducing manual workload and operational costs while improving verification speed.

This system offers the benefit of verifying transcripts directly through the on-chain explorer by simply entering the generated verification code provided by the admin. Additionally, it interacts with the Ethereum smart contract during the transcript upload process to ensure secure and tamper-proof data handling.

Furthermore, the modified blockchain architecture introduces enhanced scalability solutions, making it adaptable for nationwide and international transcript management. The adoption of advanced cryptographic security measures safeguards sensitive academic data, ensuring compliance with privacy regulations and institutional policies. Overall, this system presents a reliable, secure, and future-proof approach to academic credential management. Future research will focus on AI-driven verification mechanisms to further enhance system capabilities and adoption on a global scale.

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