APPLYING BLOCKCHAIN TECHNOLOGY GRADE MANAGEMENT IN UNIVERSITY: A CASE STUDY IN VIETNAM

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ABSTRACT

In modern education, transparency in grade management is essential to maintaining fairness and trust among schools, teachers, and students. Traditional systems that rely on centralized databases are vulnerable to cyberattacks, unauthorized modifications, and system failures, which may lead to data loss or manipulation. Therefore, a new technological solution is required to ensure secure, transparent, and fair grade management, preventing fraud and enabling easy verification for all stakeholders. This study addresses this need by applying blockchain technology to develop a grade management website that ensures security and transparency through the use of blockchain and smart contracts. The system securely manages student grades in a tamper-proof manner across courses and semesters. It involves building a private blockchain, deploying smart contracts, and integrating blockchain interaction libraries. A user-friendly interface enables students and teachers to view grades by semester, course, or cumulative results, with every grade update recorded transparently on the blockchain.

1. INTRODUCTION

Blockchain technology offers a decentralized, immutable ledger that ensures data integrity and security, contrasting sharply with traditional centralized databases vulnerable to unauthorized modifications and single points of failure [1,2]. In the educational sector, blockchain adoption has expanded across various domains, including certificate management, competency tracking, and copyright protection [3,4]. However, existing literature indicates that most solutions focus on credential verification rather than the continuous, secure management of student grades [5].

Traditional grade management systems often lack transparency and robust audit trails, leaving data prone to manipulation and errors [6,7]. This study addresses these limitations by proposing a blockchain-based grade management system. By leveraging smart contracts, the system ensures that every grade modification is permanently recorded and transparently verifiable [8]. Contributions to this study include:

Apply Blockchain technology to build a transparent and secure grade management system. The system supports key functionalities such as viewing, adding, and editing grades; searching for students and courses; and managing academic records through a user-friendly web interface.

Record all grade modifications directly on the Blockchain, ensuring that the data cannot be altered or forged. This system maintains integrity and transparency throughout the grade management process.

Integrate a digital wallet to enhance security and authenticate transactions through digital signatures and transaction fees [9]. Blockchain-related operations require lecturers to use a digital wallet, ensuring safety and transparency in the management process.

The structure of this study is as follows: Section 2 details the system design, including system specifications, consensus algorithms, and smart contract implementation. The results are then presented and analyzed in Section 3. Finally, the study concludes with a summary and discussion of potential future directions in Section 4.

2. METHOD

In this section, we will present the core methods and processes applied in the development of the grade management system for this study. First, we will discuss the interface requirements, focusing on design elements to ensure an intuitive and user-friendly experience. Next, the functional requirements will clarify the key features and operations of the system. Additionally, we will analyze and provide a detailed description of the construction and integration of the private blockchain with the system. Finally, the analysis and design of smart contracts will be presented, emphasizing their role in securing transactions and automating system processes. As illustrated in Fig. 1, the system workflow for adding or editing student grades involves interactions among three main components: the front-end, the back-end, and the blockchain. When a user initiates a request to add or modify grades via the front-end interface (Step 1), the request is simultaneously sent to the blockchain (Step 2) and the back-end (Step 3), including

necessary data such as StudentID, CourseSectionID, and Grade. Upon receiving the request, the blockchain generates a transaction hash and processes the input through smart contracts. This hash is also forwarded to the back-end to verify and monitor the transaction status. The back-end (Step 4) temporarily updates the local database with the submitted grade data and returns the result to the front-end. Meanwhile, it listens for the blockchain's transaction confirmation (Step 5). Once the blockchain completes the transaction (Step 6), the back-end verifies the result and performs appropriate actions (Step 7) - either committing the transaction and logging it if successful, or rolling back the data if the transaction fails. In this workflow, critical information-such as encrypted grade data, student identifiers, and course section codes-is recorded on the blockchain to ensure immutability and transparency. In contrast, auxiliary data such as user profiles, course details, and query-optimized caches is maintained in the off-chain backend database to enhance system performance.

2.1. Interface requirements

The user interface of the student grade management system plays a crucial role in creating a convenient and efficient user experience. To meet the diverse needs of students and faculty, the interface must include specific features and requirements.
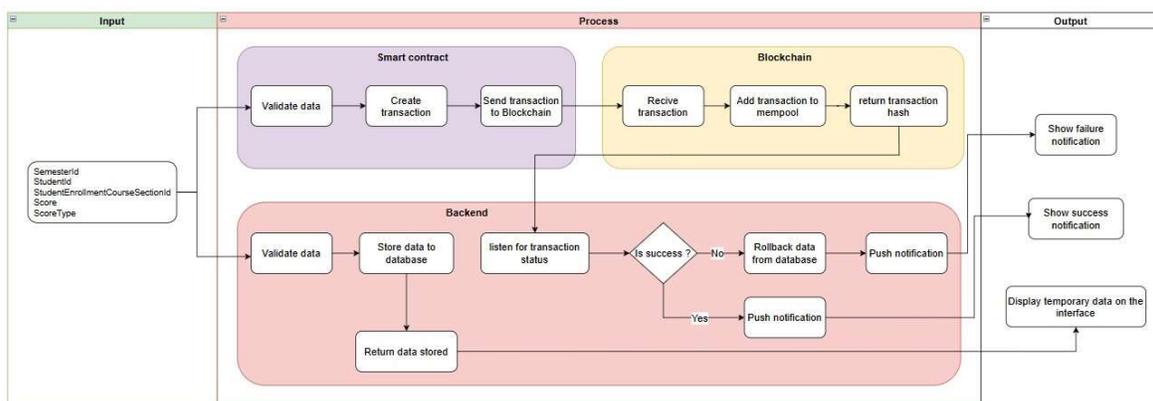

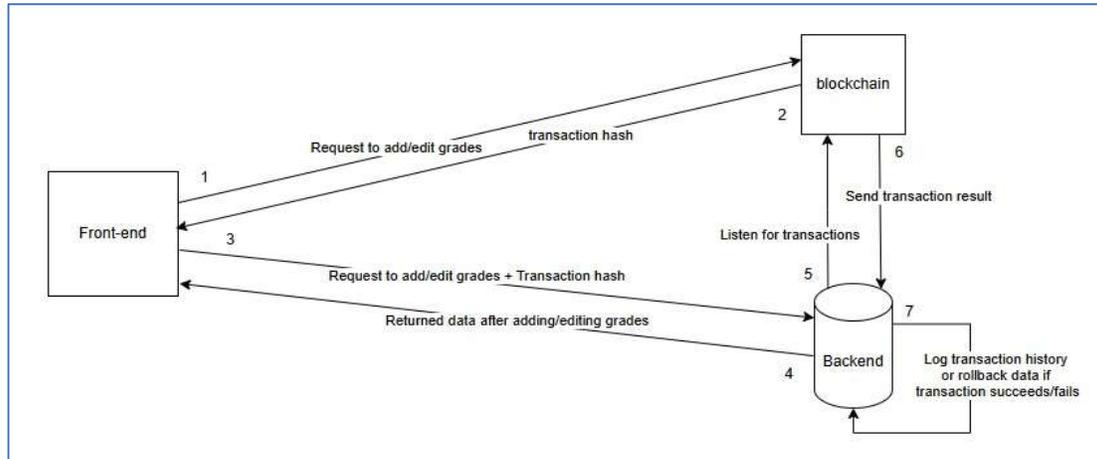**Figure 1. System workflow diagram**

Figure 2. Detailed Workflow Diagram

First, the interface should be simple and easy to use. Users (students, lecturers, and administrators) should be able to search, browse, and view student grades effortlessly, without unnecessary complications. Smart categorization and filtering systems should enable quick searches based on criteria such as courses, semesters, students, or grade ranges. Transparency and security are indispensable elements.

Grade information should be displayed clearly, including details on the evaluation process, grade modification history, and lecturer-related information. Additionally, the interface should incorporate icons and notifications to help users easily identify grade transactions and ensure changes are secure and accurate, preventing any unauthorized alterations. The interface should also be optimized for mobile and desktop experiences, ensuring flexibility and convenience. This allows users to access and utilize the system anytime, anywhere.

2.2. Functional requirements

The system implements a strict Role-Based Access Control (RBAC) model for three primary actors:

Administrators: Manage system entities (users, courses) but are explicitly restricted from modifying grades to ensure data neutrality.

Lecturers: Possess write privileges to input or update grades for their assigned courses.

Students: Maintain read-only access to their academic records.

Fig. 2 illustrates the hybrid data processing architecture. User inputs (Student ID, Course Section ID, Score) undergo dual-layer validation via both the backend and smart contracts. Upon validation, the smart contract submits the transaction to the blockchain. Concurrently, the backend caches data off-chain for immediate responsiveness and listens for transaction events. Data consistency is enforced through a confirmation mechanism: successful block inclusion finalizes the record, while transaction failure triggers an automatic rollback of the off-chain cache, ensuring synchronization between the immutable ledger and the user interface.

2.3. Private chain analysis and design

Building a private chain for the grading management system requires meeting several criteria to ensure it is suitable for its purpose and scale of implementation. First, the system must meet requirements for security and data integrity, ensuring that information related to student grades is stored securely and cannot be modified or deleted once recorded. High performance is a critical factor, allowing the blockchain to process transactions quickly for

real-time recording and querying of grades, without affecting user experience. Additionally, the transparency and verifiability of blockchain enable grade data to be stored publicly while ensuring that only authorized actors, such as lecturers or administrators, can perform data writing operations. The system should be designed with scalability as a core consideration, allowing for the seamless integration of additional features or modules as needed. In particular, ensuring compatibility with tools such as MetaMask is essential for facilitating secure and convenient transaction signing and user authentication

2.3.1. PoA Consensus Algorithm

In the student grading management system, Proof of Authority (PoA) is chosen as the consensus algorithm instead of Proof of Work (PoW) or Proof of Stake (PoS). PoA is a lightweight consensus mechanism that uses validator nodes selected based on identity or trustworthiness, helping to save resources, reduce costs, and provide high performance. This is suitable for the requirements of a private blockchain system, where complete decentralization, as in public networks, is not necessary. Compared to PoW, PoA is energy-efficient and has a fast transaction confirmation speed, while PoS is more complex and depends on staked assets. PoA is also easier to implement and maintain, making it ideal for a private network with tightly controlled validator nodes [10].

Therefore, PoA is the optimal choice, ensuring data integrity and efficiency for the student grading management system.

2.3.2. Designing Nodes in the Network

The private network is synchronized via a central Bootnode and comprises three operational nodes:

Node 1 (Primary Validator): Operates under the PoA consensus to validate transactions and create blocks. It serves as the main RPC gateway (port 8545) for the application, handling automated transaction signing and external integrations via standard APIs (eth, web3).

Nodes 2 & 3 (Full Nodes): Function as non-validating peers to ensure data redundancy and fault tolerance. They maintain real-time synchronization with Node 1 to support load balancing and prevent data loss.

2.3.3. Private chain deployment using Geth

The genesis file is the first configuration in deploying a private blockchain, setting up basic network parameters such as node addresses, consensus mechanism, block size, and network rules. For a private chain, the genesis file defines the genesis block, initial Ether allocation, and consensus mechanisms such as PoA or PoW. It creates an independent blockchain environment, ensuring that nodes in the network synchronize and interact correctly from the start, while also allowing for configuration of security and access controls.
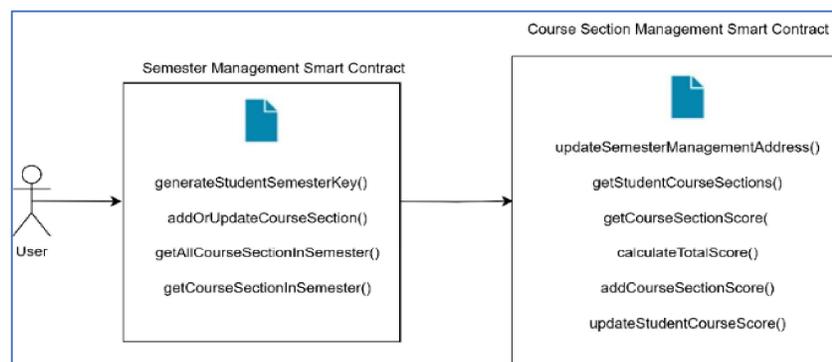

Figure 3. Our smart contract structure

2.4. Smart contract analysis and design

To optimize gas costs and scalability while ensuring data integrity, the system adopts a hybrid storage strategy. Only critical immutable data (grades, IDs of students, courses, and lecturers) is stored on-chain. Detailed metadata (names, personal information) is stored off-chain in a MySQL database. This modular approach ensures GDPR compliance and facilitates easy integration with external systems.

2.4.1. Smart Contract Design

The system consists of two main Smart Contracts: Semester Management and Course Section Management as shown in Fig 3. They are divided into modules for easier maintenance, expansion, and access control. The system uses complex data types (structs and mappings) to store information optimally.

2.4.2. Course Information Storage Structure and Mapping

Grades are stored as uint16 values ranging from 0 to 65,535. To support decimal precision (two decimal places), raw grade values are multiplied by 100 before storage. Key mappings for data retrieval include:

StudentCourseSections: Maps a hash of studentId and semesterId to an array of enrolled courses.

CourseSectionGrade: Stores detailed grade information, indexed by student and course section IDs.

CourseSectionTeachers:Maps courseSectionId to the assigned lecturer's Ethereum wallet address for authorization.

2.4.3. Check Contract and Lecturer Rights

To ensure security, the system implements specific modifiers:

onlySemesterManagement: Restricts function execution to the Semester Management contract by verifying msg.sender. Transactions from unauthorized addresses are reverted.

onlyTeacher: Validates the caller via tx.origin to ensure that only the assigned lecturer can modify grades or course details.

3. RESULTS

3.1. Effective grade management

The system successfully establishes a secure grade management platform with comprehensive functionalities for Administrators and Lecturers. Key technical achievements include:

- Synchronizes data between off-chain databases (for performance) and a private blockchain (for immutability), ensuring both speed and transparency.

- Smart contracts enforce valid grade modifications via MetaMask authentication, eliminating fraud risks.

- An automated rollback mechanism maintains data consistency during network failures, while a full transaction history allows for precise auditing.

However, the system faces challenges regarding scalability and cost efficiency. Bulk grade updates currently consume significant Gas, potentially depleting network resources. Furthermore, the rollback process for large datasets remains complex. Future development will focus on integrating an infinitely mintable ERC20 token to stabilize operational costs and optimizing the error handling logic for mass data transactions.

3.2. Storing transactions on the Blockchain

3.2.1. Transparently store scores and efficiently retrieve transaction history

The system records every grade modification as an immutable blockchain transaction, preventing unauthorized alteration. This transparency allows students to independently track their academic history and empowers administrators to validate grades directly from the ledger. By eliminating reliance on manipulatable internal logs common in traditional databases, the system ensures absolute data authenticity and simplifies the auditing process.
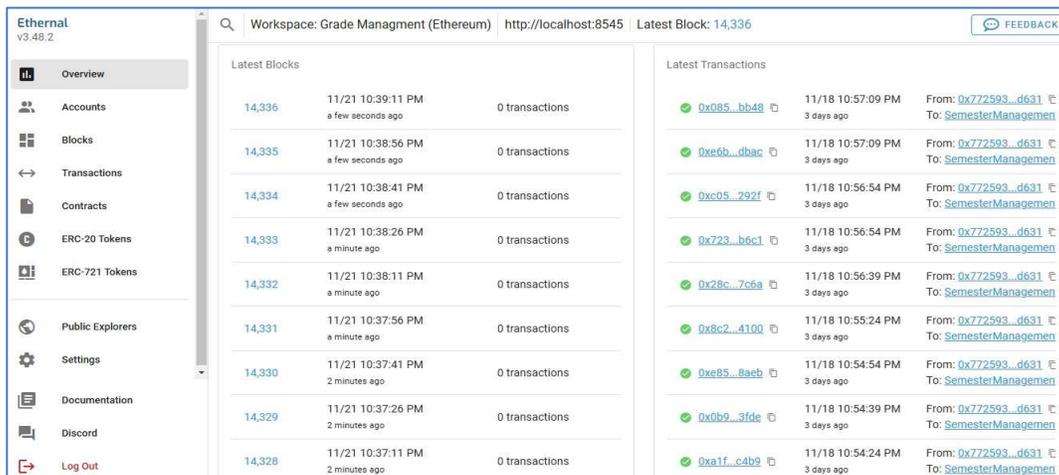
Figure 4. Blocks and transactions are recorded in the system

3.2.2. Data integrity assurance

To ensure robust data integrity, the system employs a comprehensive security framework combining network hardening with rigorous validation protocols. The blockchain network mitigates the risk of 51% attacks by enforcing a decentralized architecture with a minimum of two validator nodes. Each node is secured through strict access controls, including Cross-Origin Resource Sharing (CORS), credential-based authentication, and the restriction of exposed APIs to essential functions only.

Simultaneously, data consistency is guaranteed through a parallel synchronization strategy. Input data undergoes a three-tier validation process across the client, backend, and smart contract layers before blockchain submission. To address potential network failures, an automatic rollback mechanism is integrated; if an on-chain transaction fails, the system immediately reverts the corresponding off-chain records, thereby maintaining perfect alignment between the database and the immutable ledger.

3.2.3. Cost and Performance Optimization

The system minimizes costs via a private Proof of Authority (PoA) architecture and lightweight smart contracts. This approach results in an average transaction fee of 0.0002 ETH, significantly lower than Ethereum Mainnet (~0.0012 ETH), allowing approximately 5,000 transactions per 1 ETH. Performance stress tests confirmed a 100% success rate with zero synchronization errors (Fig. 4). With a configured 15-second block time, transactions are validated within 2–3 seconds-comparable to Ethereum PoS (~12s) and vastly superior to Bitcoin-ensuring a seamless, low-cost user experience.

3.3. Comparison between traditional point management and blockchain-based solution

We conducted a comparison between traditional grade management methods and the technology we implemented, as presented in Table 1. In traditional systems, grade data is susceptible to unauthorized access or modification. In contrast, with blockchain, all transactions are transparent and immutable. This distinction highlights the superiority of blockchain in creating a modern, secure, and reliable grade management system

Table 1. Comparison between traditional point management and blockchain-based solution

Criteria	Traditional Point Management	Blockchain-based point management
Transparency	Depends on the system administrator or central database. Information can be edited without leaving a trace.	Data stored on the blockchain is public, transparent, and cannot be edited after recording.

Criteria	Traditional Point Management	Blockchain-based point management
Data integrity	Vulnerable to loss or modification due to system failure or security incidents.	Each transaction is assigned a transaction hash, ensuring integrity and immutability.
Security	Data is often stored centrally, making it vulnerable to attack or unauthorized access.	Data is encrypted and stored on a decentralized network, only authorized people can make transactions.
Long-term feasibility	Traditional systems need constant upgrading to meet the demands.	Blockchain is scalable and can be easily integrated with new systems.
Access Management	Relies on traditional security mechanisms like passwords.	Use MetaMask and private keys to authenticate transactions, ensuring only authorized people can perform operations.
Availability	Centralized systems are vulnerable to disruption if the server crashes.	Blockchain operates on a decentralized network, which minimizes the risk of disruption.
Fraud and error	Most likely due to a lack of transparent control mechanism.	Data is validated through consensus (PoA), eliminating fraud and minimizing errors.
Traceability	Difficult to retrieve edit history or change points.	Every change is recorded on the blockchain, the origin and time of the transaction can be checked.
Operating costs	Depends on the server and the admin team.	Lower maintenance costs in the long run, due to the decentralized blockchain network and automation of many processes.

4. CONCLUSION

This study successfully establishes a private blockchain framework that guarantees grade transparency and security via smart contracts. By mitigating the vulnerabilities of centralized databases such as data tampering and unauthorized access, the system provides a tamper-proof environment that fosters trust among stakeholders. Future work will prioritize optimizing system scalability for high-volume datasets. Additionally, we aim to enhance interoperability with Learning Management Systems (LMS) and expand the ledger to encompass broader academic records, including attendance and certifications, creating a comprehensive decentralized educational ecosystem.

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ỨNG DỤNG CÔNG NGHỆ BLOCKCHAIN TRONG QUẢN LÝ ĐẠI HỌC: NGHIÊN CỨU TRƯỜNG HỢP TẠI VIỆT NAM

TÓM TẮT

Trong nền giáo dục hiện đại, tính minh bạch trong quản lý điểm số là yếu tố thiết yếu để duy trì sự công bằng và tin tưởng giữa nhà trường, giáo viên và người học. Các hệ thống truyền thống dựa trên cơ sở dữ liệu tập trung dễ bị tấn công mạng, sửa đổi trái phép và lỗi hệ thống, dẫn đến mất mát hoặc thao túng dữ liệu. Do đó, cần một giải pháp công nghệ mới để đảm bảo quản lý điểm số an toàn, minh bạch và công bằng, ngăn ngừa gian lận và cho phép xác minh dễ dàng cho tất cả các bên liên quan. Nghiên cứu này giải quyết nhu cầu đó bằng cách áp dụng công nghệ blockchain để phát triển một trang web quản lý điểm số đảm bảo tính bảo mật và minh bạch thông qua việc sử dụng blockchain và hợp đồng thông minh. Hệ thống quản lý điểm số của người học một cách an toàn và không thể bị giả mạo trên các khóa học và học kỳ. Hệ thống bao gồm việc xây dựng một blockchain riêng tư, triển khai các hợp đồng thông minh và tích hợp các thư viện tương tác blockchain. Giao diện thân thiện với người dùng cho phép người học và giáo viên xem điểm theo học kỳ, khóa học hoặc kết quả tích lũy, với mọi cập nhật điểm số được ghi lại minh bạch trên blockchain.

Từ khóa: Công nghệ Blockchain, minh bạch điểm số, website quản lý điểm số