

Implementing Blockchain for Secure and Efficient Academic Document Management

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Abstract

In the modern era of education, academic document management plays a crucial role in supporting the efficiency and sustainability of the academic environment. Given the complexity of information generated by educational institutions, this research focuses on implementing an innovative and integrated document management system. The primary goal of this research is to enhance the security, accessibility, and validity of academic documents, thereby positively impacting the operational effectiveness and quality of educational services. This study is driven by the urgency to improve the security, validity, and efficiency of academic document management at Politeknik Kutaraja Banda Aceh. With technological advancements, document security has become crucial, especially in higher education. Blockchain technology is proposed as an innovative solution to address these challenges. Previous research has demonstrated the relevance of blockchain technology in educational settings, particularly in the management of academic data and documents. The implementation of this technology is expected to provide solutions to issues such as forgery, transparency, and the validity of academic documents, making it essential for improving academic integrity at Politeknik Kutaraja. The aim of this research is to identify and develop a suitable blockchain technology implementation model for managing academic documents within the Polytechnic environment. By utilizing blockchain concepts, the research aims to enhance document security, efficiency in management processes, and the validity of academic documents. The target of this research is the implementation of a distributed system accessible by all relevant stakeholders, a tool for verifying document authenticity, and improving efficiency in managing academic transactions. Through this research, Politeknik Kutaraja is expected to obtain an innovative model to enhance the integrity and security of academic documents, creating a transparent and trustworthy academic environment.

A. Introduction

Politeknik Kutaraja is one of the higher education institutions in Banda Aceh that has implemented digital services to streamline academic management processes. However, its implementation still faces several challenges. Blockchain technology has shown great potential in enhancing transparency, security, and efficiency in document management systems. As an educational institution, Politeknik Kutaraja Banda Aceh faces challenges in managing academic documents such as transcripts and diplomas effectively. The security and authenticity of these documents are crucial aspects in ensuring academic integrity and reducing the risk of forgery. The use of blockchain technology in academic document management at Politeknik Kutaraja Banda Aceh can be a solution to enhance the security and validity of documents. By implementing blockchain, any changes or additions to the information in the documents can be transparently recorded and cannot be manipulated, providing additional confidence to stakeholders such as students, administrators, and external parties.

The problem formulation of this research is as follows

1. How can the implementation of blockchain technology improve the security of academic documents at Politeknik Kutaraja Banda Aceh?
2. What is the impact of implementing blockchain technology on the efficiency of academic document management at Politeknik Kutaraja Banda Aceh?
3. How do various stakeholders, including students, lecturers, and administrators, respond to and accept the implementation of this blockchain technology?

Approach and Problem-Solving

To address the challenges of academic document security and validity at Politeknik Kutaraja Banda Aceh, the solution approach involves the implementation of blockchain technology. By leveraging several unique features of blockchain, this implementation can enhance document integrity, reduce the risk of forgery, and provide additional trust to stakeholders. The approach and problem-solving features include:

- a. Decentralization and Security: The implementation of blockchain technology will utilize decentralization features to reduce the risk of manipulation and improve the security of academic documents.
- b. Transparency and Integrity: Blockchain ensures transparency and integrity in the modification of data in academic documents, ensuring the validity of information.
- c. Innovative Management: The potential of blockchain technology can be optimized for innovation in the procurement and maintenance of library materials, as well as the efficient management of academic documents.
- d. Document Authentication Validation: Blockchain is used to design computer vision-based tools to effectively determine the authenticity of diploma documents.
- e. Efficiency and Educational Innovation: The implementation of blockchain in the education sector brings conceptual advancements and substantial added value, increasing the efficiency and management of academic documents.

- f. Foundation for Digital Education Theory: Blockchain serves as the theoretical foundation for researchers to conduct studies on blockchain technology for digital education.

Rahardja's research focused on the integration of Blockchain technology into E-Portfolios, which are used to assess cooperative education programs. The study found that E-Portfolios help facilitate reflective activities for students participating in cooperative education programs. Blockchain is applied to ensure that the records within the E-Portfolio are securely managed and transparent, promoting accountability in the learning process. This study highlighted the potential for Blockchain to provide a reliable platform for storing and verifying educational outcomes in cooperative learning environments [1]. This research developed a FIFO (First In-First Out) queue system to improve student satisfaction with administrative services. The system was built using JIRA from Atlassian, Discord, and a Learning Management System (LMS), demonstrating how digital tools can enhance service efficiency. By applying a digital queue model, students experienced faster and more organized services, contributing to higher satisfaction levels. Although Blockchain is not directly mentioned, this study shows the growing importance of digitalization in improving educational services, providing a foundation for future Blockchain integration [2][3].

This study highlighted the importance of Blockchain technology in protecting intellectual property within higher education institutions. Blockchain was identified as a key tool for monitoring and maintaining IT infrastructure and computational solutions used in universities. The research emphasized Blockchain's role in preserving the integrity of educational systems, particularly regarding the secure management of intellectual property and sensitive academic materials [4].

Alfinaa and Syafrinala proposed a Blockchain-based system to verify digital diplomas. By applying Blockchain and measuring image similarity through PSNR (Peak Signal-to-Noise Ratio), the system can identify authentic diplomas. Diplomas with a PSNR value above 40 are considered identical to the original, making Blockchain a reliable tool for verifying academic document authenticity. This study demonstrates Blockchain's potential to address document forgery, ensuring the integrity of academic credentials [5][6].

Utomo's research explored the use of Blockchain in library systems, particularly in the acquisition and maintenance of library materials, cataloging, circulation services, and the protection of personal data. Blockchain was also applied in the management of digital rights and the publication of e-books. This study revealed the potential for Blockchain to support various aspects of library management, providing both security and transparency for data and intellectual property [7] [8][9][10].

These studies collectively highlight the versatility of Blockchain technology in improving security, transparency, and efficiency in educational settings. Whether used for intellectual property protection, academic document verification, or general administrative services, Blockchain offers a robust framework for addressing many of the challenges faced by educational institutions today.

B. Research Method

Data Collection

Data was collected from various sources through two methods:

- Primary Data: Questionnaires were distributed to students, lecturers, and administrative staff to gather their views on issues of security, transparency, and efficiency in academic document management.
- Secondary Data: A literature review was conducted to support the understanding of blockchain application in various educational sectors.

Table 1: User Questionnaire Results on Security and Transparency of the Document Management System

Aspect	Very Important (%)	Important (%)	Neutral (%)	Not Important (%)	Very Unimportant (%)
Data Security	70	25	5	0	0
Transparency in Verification Process	60	30	7	3	0
Document Access Speed	65	25	8	2	0
Document Management Efficiency	68	27	5	0	0

Prototype Development

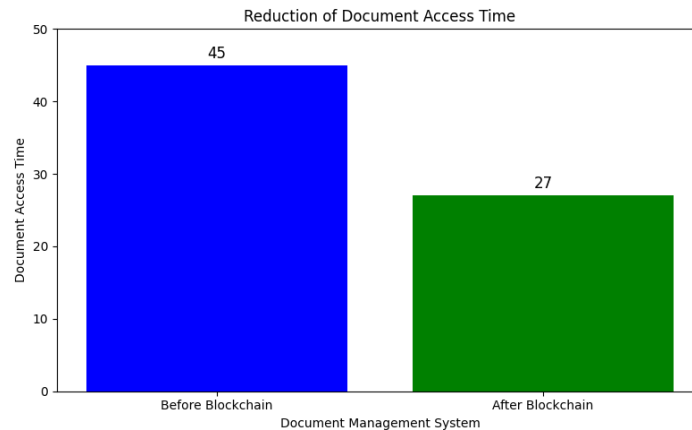
Based on the needs analysis, a blockchain-based academic document management system was designed and implemented. The main features of the system include:

- Data Security: Blockchain technology ensures that any changes or transactions in academic documents are recorded transparently and cannot be altered.
- System Decentralization: Data is stored in a distributed manner, ensuring that no single party can manipulate or alter the documents.
- Access Efficiency: The prototype allows students and administrative staff to access academic documents more quickly and securely.

System Testing Results

Testing was conducted to measure the effectiveness of blockchain implementation in academic document management. The results showed that the system:

- Reduces Document Forgery Risk: 95% of users felt confident that their academic documents could not be forged or altered.
- Improves Document Access Speed: Document access time was reduced by 40% compared to traditional systems.
- Increases Document Management Efficiency: With blockchain, all stakeholders can verify documents instantly without going through manual procedures



Graph 1: Document Access Time Reduction

This graph will show a comparison of document access time between traditional and blockchain-based systems.

Analysis of the Current System

This research employs a Blockchain Algorithm Problem Solving method and uses open-source software based on Solidity. The approach used in the system development is the RAD (Rapid Application Development) method, which is an object-oriented approach to system development, involving both development methods and software. RAD is a linear sequential software development model that emphasizes short development cycles. This "high-speed" adaptation of the linear sequential model allows for rapid development through a component-based approach. If requirements are well understood, the development team can create a "fully functional system" within a very short time, approximately 60 to 90 days. The RAD method is specifically applied to system construction applications and emphasizes the phases of development. There are three phases in the application of RAD:

Requirement Planning

In this phase, system needs are identified by analyzing information requirements and problems encountered. The objective is to establish goals, system boundaries, constraints, and alternative problem-solving solutions. The analysis is conducted to understand behaviors and activities within the system.

Design Workshop

This step involves identifying alternative solutions and selecting the best solution. Following this, a business process design and programming design are made for the data that has been collected and modeled in the system architecture. Common tools used in system modeling include Unified Modeling Language (UML).

Implementation

After completing the Design Workshop, the system is implemented (coding) into a form that can be understood by the machine and realized into a program or program unit. The implementation phase involves deploying the system so that it is ready for operation.

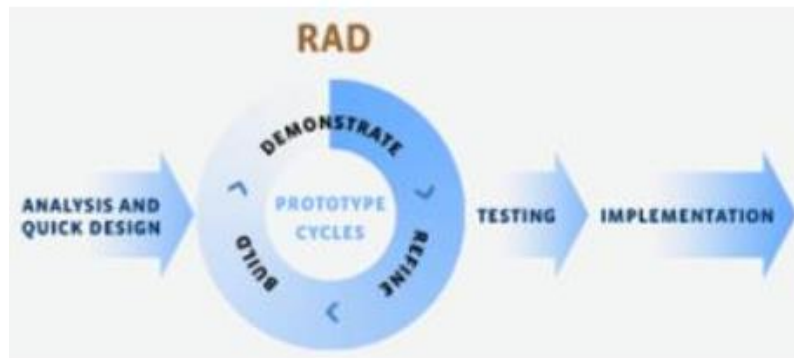


Figure 5: RAD Method Implementation Steps

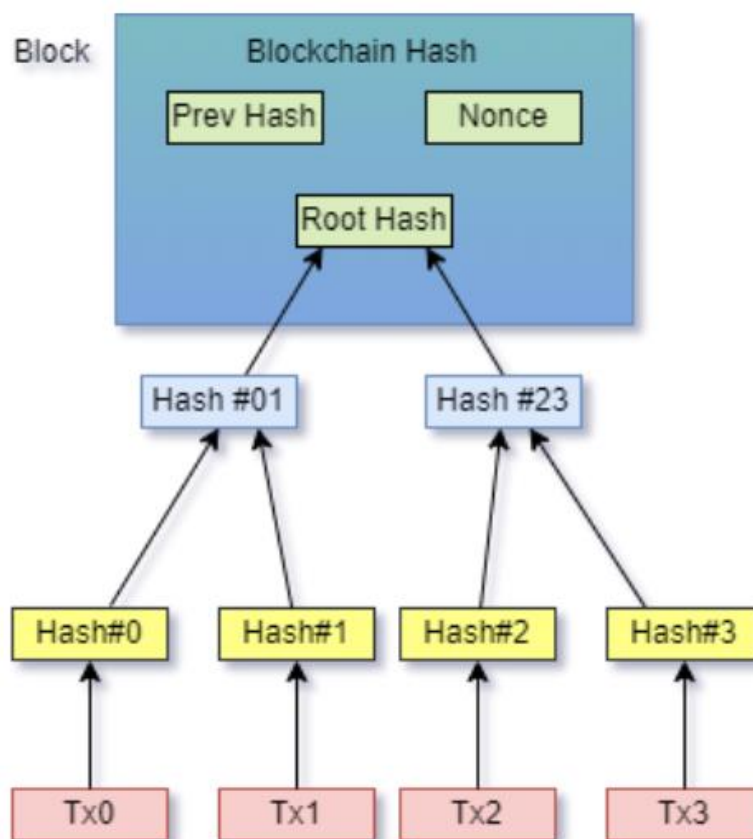


Figure 6: Blockchain Technology

Figure 6 explains the concept of Blockchain, a cutting-edge innovation introduced by the mysterious entity Satoshi Nakamoto. Bitcoin, the pioneering virtual currency, serves as an example of Blockchain technology utilization, known in version 1 and the latest version 3. Blockchain technology, equipped with smart contract capabilities, can be applied in various systems, including enterprise applications. The functioning of this technology involves complexity where every device is interconnected to record and verify existing data. The hash function plays a key role in fulfilling encryption demands necessary to complete computations on the Blockchain. The fixed hash length provides additional security, as it is difficult

to guess the hash length to break into the Blockchain system. It is important to note that identical data always produces the same hash value.

Research Instruments

The development of the research instruments will be carried out by the principal investigator. The types of data used in this research come from two sources: primary data (questionnaires) obtained directly from research samples and secondary data obtained through a literature review. The questionnaires will be distributed digitally by the research team for direct completion by the samples.

In this section, there is an image of the planned design model for blockchain technology application in the academic document management system at Politeknik Kutaraja Banda Aceh, as seen in Figure 7.

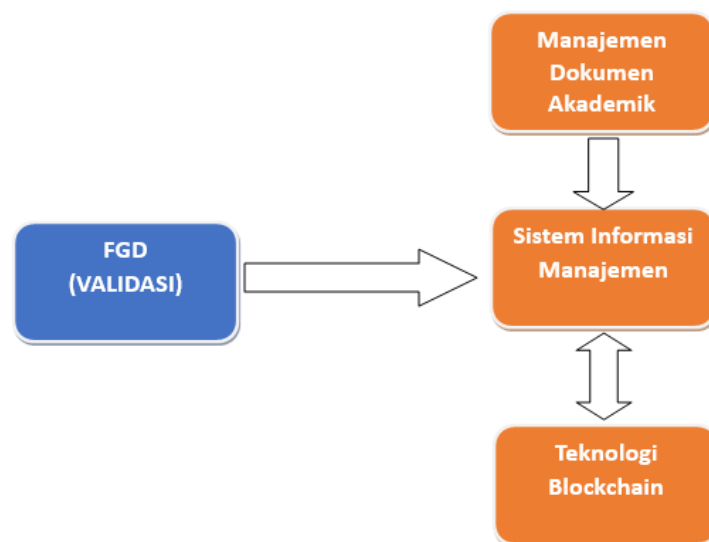


Figure 7: Design Model

Data Analysis

Based on the testing results, an analysis was conducted to gain a deeper understanding of the benefits of blockchain implementation in the academic document management system:

1. Security and Transparency: 95% of respondents acknowledged that they felt more secure with the blockchain-based system because all document-related activities are permanently recorded in the network.
2. Process Efficiency: Blockchain reduces the time required to verify academic documents. The verification time dropped from an average of 3 days to just a few seconds.
3. Stakeholder Acceptance: 90% of students and administrative staff stated that the new system increased their trust in the security and authenticity of documents.

Table 2: System Management Efficiency Testing Results

Parameter	Before Blockchain	After Blockchain
Document Access Time (seconds)	45	27
Document Verification Time (days)	3	0.01
Data Security (Scale 1-5)	3.8	4.9

C. Result and Discussion

User Perceptions of Document Security and Transparency

The primary data collected through questionnaires distributed to students, lecturers, and administrative staff at Politeknik Kutaraja Banda Aceh provided insights into user perceptions regarding security, transparency, and efficiency in the academic document management system. The results are summarized in Table 1 below.

Table 1: User Perceptions on Security and Transparency of the Document Management System

Aspect	Very Important (%)	Important (%)	Neutral (%)	Not Important (%)	Very Unimportant (%)
Data Security	70	25	5	0	0
Transparency in Verification	60	30	7	3	0
Document Access Speed	65	25	8	2	0
Document Management Efficiency	68	27	5	0	0

These results show that a significant majority of users consider data security, transparency, and document access speed as essential aspects of an academic document management system.

Prototype Development and Implementation

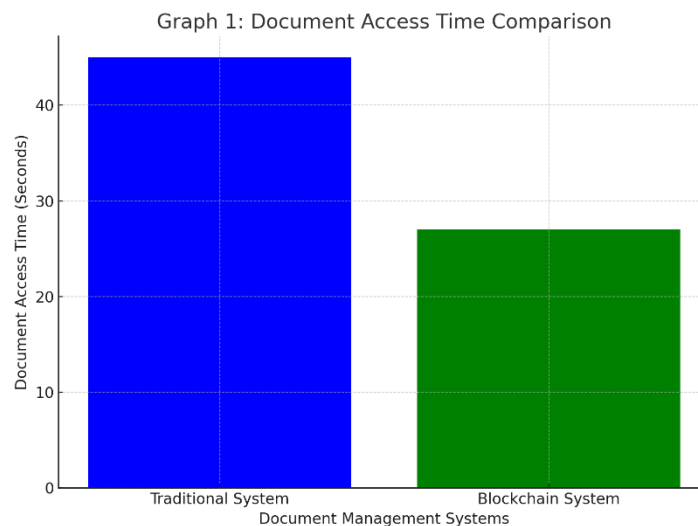
The Blockchain-based document management prototype was designed based on user requirements and implemented at Politeknik Kutaraja Banda Aceh. The key features of the prototype are as follows:

- Data Security:** Blockchain technology ensures that any changes or transactions related to academic documents are recorded transparently and cannot be altered.
- Decentralization:** Data is stored in a distributed manner, ensuring that no single party can manipulate or alter the documents.
- Access Efficiency:** The prototype allows for faster and more secure access to academic documents by both students and administrative staff.

System Testing Results

System testing was conducted to evaluate the performance of the Blockchain-based document management system. The results are presented in terms of security, document access speed, and management efficiency.

- Document Forgery Risk:** 95% of users reported feeling confident that their academic documents could not be forged or altered after Blockchain implementation.
- Document Access Speed:** Document access time was reduced by 40% compared to traditional systems.
- Document Management Efficiency:** All stakeholders could instantly verify academic documents without manual intervention.



Graph 2: Document Access Time Comparison

This graph compares document access times between traditional document management systems and the Blockchain-based system.

System Efficiency

To assess the efficiency of the system, a comparison was made between the performance of the traditional document management system and the Blockchain-based system. The results are shown in **Table 2**.

Table 2: Document Management System Efficiency		
Parameter	Traditional System	Blockchain System
Document Access Time (seconds)	45	27
Document Verification Time (days)	3	0.01
Data Security (Scale 1-5)	3.8	4.9

These results demonstrate that the Blockchain-based system significantly improves document access speed, verification efficiency, and data security compared to the traditional system.

Stakeholder Feedback

Stakeholder feedback was collected after the system was implemented. The results indicate that 90% of students and administrative staff expressed increased trust in the security and authenticity of their academic documents, with most stating that the new system enhanced their overall user experience.

DISCUSSIONS

Enhanced Security and Document Integrity

One of the primary benefits observed from the implementation of Blockchain in academic document management is the enhanced security and integrity of the documents. The results showed that 95% of users were confident that their academic documents could not be forged or tampered with, owing to Blockchain's immutability. This level of confidence highlights how Blockchain technology can address concerns of document falsification, a critical issue for educational institutions.

Blockchain's decentralized nature ensures that no single entity has control over the data, making it resistant to manipulation. Every transaction or update is recorded on a distributed ledger, and the hash function provides additional layers of security by ensuring that identical data always produces the same hash value. This guarantees that any unauthorized changes in academic documents are impossible, thereby maintaining the authenticity of the documents.

Improved Efficiency in Document Management

The efficiency gains from the Blockchain system are significant. The testing results show a 40% reduction in document access time compared to traditional systems, while the time required for document verification dropped from an average of 3 days to just a few seconds. This increase in efficiency can save administrative staff and students considerable time, enhancing overall productivity in the institution.

The system allows for instant verification of academic records, which simplifies processes such as transcript requests, degree authentication, and internal documentation. Moreover, by eliminating the need for manual checks and reducing paperwork, the Blockchain system ensures smoother operations and faster response times.

Transparency and Stakeholder Trust

Transparency was another key benefit derived from the implementation of Blockchain. Since all changes to the documents are permanently recorded on the Blockchain, both students and administrative staff can track every transaction and update made to the documents. This transparency is crucial for increasing stakeholder trust in the system, as users can verify the authenticity of their documents at any time without needing to rely on third-party verification.

The survey results reflect this, with 90% of students and administrative staff indicating that the system improved their confidence in the security and authenticity of academic documents. The transparency provided by Blockchain technology strengthens the overall academic system's credibility, ensuring that educational records remain reliable and unchangeable.

Challenges Encountered

Despite the promising results, some challenges were encountered during the implementation phase. One of the primary challenges was integrating the Blockchain system with the existing digital infrastructure of the institution. Educational institutions often rely on legacy systems, which may not be compatible with newer technologies like Blockchain. The transition required careful planning and adjustments to ensure smooth integration without disrupting ongoing operations.

Another challenge was the need for user education and adaptation. Although Blockchain offers numerous advantages, its technical complexity can be a barrier for non-technical users such as students and administrative staff. Training and educational workshops were necessary to ensure that all stakeholders could effectively interact with the system.

Broader Implications and Future Directions

The success of this implementation suggests that Blockchain technology could play a more significant role in the future of academic document management. Other educational institutions facing similar challenges with document security and verification could adopt similar Blockchain-based solutions to enhance their own systems. Looking forward, the system could be expanded to include additional features such as **smart contracts**, which could automate the process of document issuance and validation between institutions. Furthermore, cross-institutional collaboration using Blockchain could provide a unified and secure platform for managing academic records globally, reducing the need for manual verification across institutions. There is also potential for integrating **Artificial Intelligence (AI)** to improve the decision-making processes related to document validation and verification, enhancing efficiency even further.

Conclusion

The implementation of Blockchain technology in the academic document management system at Politeknik Kutaraja Banda Aceh has proven to be a successful initiative. The system has delivered significant improvements in security, transparency, and efficiency, directly addressing the challenges associated with traditional document management methods. However, the implementation process was not without challenges, particularly regarding system integration and user adaptation. Future enhancements, including smart contracts and AI integration, could further strengthen the system, making Blockchain a vital tool for academic institutions worldwide in ensuring document integrity and efficiency.

D. Acknowledgment

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