Analysis of the Use of Blockchain Technology in Student Data Management in Schools

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Analysis of the Use of Blockchain Technology in Student Data Management in Schools

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ABSTRACT
The objective of this study is to examine the implementation of blockchain technology in the administration of student data in educational institutions and evaluate its efficacy and security in comparison to conventional systems. This study utilizes a qualitative methodology and adopts a case study approach to examine the implementation of blockchain technology in multiple schools. Data were acquired through in-depth interviews with school IT/IS/IT professionals, administrators, and blockchain technology specialists, as well as research of documentation relating to student data management policies and procedures. The results of the study reveal that the application of blockchain technology in student data management has several significant advantages, including greater data security, transparency, and operational efficiency. Blockchain ensures that student data is protected and may only be accessed by authorized individuals, eliminating the danger of data leakage and manipulation. In addition, the openness given by blockchain allows for real-time tracking of data changes, permitting more accurate audits and monitoring. This study, however, revealed significant problems in the application of blockchain technology in schools, such as the need for suitable infrastructure, high implementation costs, and a lack of awareness and technical skills among school staff. In conclusion, although blockchain technology offers numerous benefits in student data management, the success of its deployment rests greatly on the technical and financial readiness of educational institutions, as well as the necessity for sufficient training and socializing for users.

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1. Introduction

Student data management in schools is a critical part of supporting successful and efficient educational administration. Student data, including personal information, academic achievement, attendance, and health records, requires a trustworthy management system to protect its integrity and confidentiality. Many schools have typically employed paper-based data management systems or conventional databases that are prone to security concerns and human error [1].

Blockchain technology has emerged as an innovative option that provides the potential to improve data management across a multitude of sectors, including education. Blockchain is a decentralized technology that offers secure, transparent, and unchangeable data storage [2]. Blockchain can alter the way corporations store and handle data by providing a more secure and transparent infrastructure [3].

In the context of student data management, blockchain has the ability to bring answers to the issues experienced by existing methods. Student data saved in the blockchain is encrypted and safeguarded by a powerful consensus mechanism, thereby lowering the danger of data leakage and illegal access [4]. In addition, blockchain allows any modifications or transactions to be stored permanently and transparently, facilitating easier and more accurate audits [5].

However, despite the considerable benefits of blockchain technology, its deployment in educational settings still confronts various difficulties. High implementation costs, the requirement for suitable technological infrastructure, and the lack of awareness and technical skills among school staff are the key problems that need to be solved [6]. Furthermore, government restrictions and policies connected to the usage of this new technology in student data management must be examined.

This study focuses on studying the application of blockchain technology in student data management in schools, evaluating its effectiveness, security, and the obstacles it encounters. This study utilizes a qualitative approach, based on case studies from many schools that have used this technology. Data were acquired through in-depth interviews with IT professionals, administrators, and blockchain technology experts and the review of school policy documents.

By researching the practical experience and perceptions of players in the field, this research intends to provide a greater understanding of the possibilities and barriers of adopting blockchain in student data management. The results of this research are expected to contribute to the academic literature in the subject of educational management and information technology, as well as provide practical advice for educational institutions considering the deployment of blockchain technology.

2. Theoretical basis

Student data management in schools has been a significant emphasis in educational administration, especially with the rapid development of information technology. One of

the latest developments that has grabbed notice is blockchain technology. To comprehend the possible impact and benefits of this technology in student data management, several basic theories and concepts need to be explained.

Blockchain Technology

Blockchain is a distributed technology that enables secure, transparent, and unchangeable data transfers. Blockchain can be implemented in several areas, including education, to improve efficiency and data security [7]. Each block in the chain holds a record of transactions validated by the network, which is subsequently added to the chain permanently, ensuring that the data cannot be changed or removed.

Data Security

Data security is one of the primary challenges in student information management. Student data contains sensitive personal information, hence it requires stringent protection. Using blockchain technology, data may be encrypted with very powerful ways, ensuring that only authorized parties can access or modify the data. Blockchain can lessen the risk of data leakage and unwanted access by providing data integrity and secrecy using improved cryptography [8].

Transparency and auditability

One of the key advantages of blockchain is the transparency it delivers. Every transaction that occurs on the blockchain is recorded openly and can be seen by all parties with authorization. This enables for easier and more accurate tracking and auditing. This transparency can build confidence between the numerous parties involved and lessen the possibility of data manipulation [9]. In the context of schools, this means that any changes to student data may be traced and validated in real-time.

Operational Efficiency

Implementing blockchain technology can also increase operational efficiency in student data management. Blockchain enables the automation of many administrative operations that formerly required manual involvement, such as student registration, grade recording, and attendance reporting. Blockchain can minimize manual effort, allowing school staff to focus more on strategic and education-oriented duties [10].

Implementation Challenges

Despite its many benefits, the adoption of blockchain technology in student data management is not without obstacles. Some of the primary challenges to blockchain adoption are high implementation costs, the requirement for suitable technology infrastructure, and a lack of understanding and technical capabilities among school staff [11]. In addition, government rules and policies connected to the usage of this technology also have an essential role in encouraging or limiting its adoption.

Case studies and practical experience

Case studies of various educational institutions that have used blockchain provide practical insights into the benefits and limitations of this technology. An in-depth review of these situations can provide a better understanding of how blockchain can be successfully utilized in student data management. The practical experiences of schools that are further advanced in using this technology can serve as a reference for other institutions who desire to follow in their footsteps [12].

Research Methodology

Research Approach

This study employs a qualitative and quantitative approach (mixed - methods) to examine the usage of blockchain technology in student data management in schools. This strategy was chosen to acquire a full understanding of the phenomenon researched through the collecting of numerical and descriptive data. The qualitative technique allows for in-depth investigation of the experiences and perspectives of blockchain technology users, while the quantitative approach gives data that can be quantified and analyzed statistically.

Development Methods

This study adopts a design-based research methodology. This process incorporates iterations of conception, implementation, evaluation, and adjustment to build successful solutions in complex circumstances. The main steps in this strategy include:

a. Problem Identification and Goal creating: Identifying important difficulties in student data management and creating research objectives.
b. Prototype Development: Design and develop a prototype of a blockchain-based student data management system.
c. Implementation and Data Collection: In chosen schools, implement the prototype and collect data on performance and user perceptions.
d. Evaluation and Revision: Analyze the acquired data to determine the prototype's effectiveness and make adjustments based on the findings.
e. Dissemination and input: distributing research results and receiving input from end users for future development.

Research variable

This research involves two primary categories of variables.

a. Independent Variable: Blockchain technology employed in student data management systems. This includes qualities such as security, transparency, and operational efficiency.
b. Dependent Variable: Effectiveness of student data management, measured by metrics such as data dependability, user satisfaction, and time and cost efficiency.

Data collecting

The data in this study were acquired utilizing several ways, namely:

a. Survey: A questionnaire was issued to school personnel and administrators who utilize blockchain technologies to manage student data. The survey aims to acquire quantitative data on user attitudes and experiences.
b. In-depth Interviews: Semi-structured interviews were performed with numerous survey participants to acquire deeper qualitative insights into their experiences with blockchain technology.
c. Observation: Direct observation is undertaken during system implementation to examine the data management process and user engagement with the system.
d. Documentation: Collect associated documentation, such as system performance reports, data management records, and school rules surrounding information technology.

Data Processing and Verification Techniques

Data received from diverse sources will be analyzed using several methodologies, namely:

a. Descriptive Analysis: Quantitative data from the survey will be evaluated descriptively to provide an overview of user perceptions and experiences.
b. Thematic Analysis: Qualitative data from interviews and observations will be evaluated using thematic analysis to uncover significant themes and emerging patterns.
c. Data Triangulation: To boost validity and dependability, data gathered from multiple data gathering approaches will be compared and confirmed through triangulation.
d. Statistical Tests: Statistical tests such as regression and correlation will be used to assess the relationship between independent and dependent variables.

Data verification

To assure the legitimacy and dependability of the data, the following verification measures are taken:

a. Triangulation: Verifying conclusions utilizing multiple data sources and data collection methodologies.
b. Member Checking: To ensure accuracy, confirm findings and interpretations with research participants.
c. Peer Debriefing: Discussing findings and interpretations with peers to acquire additional views and decrease biased.

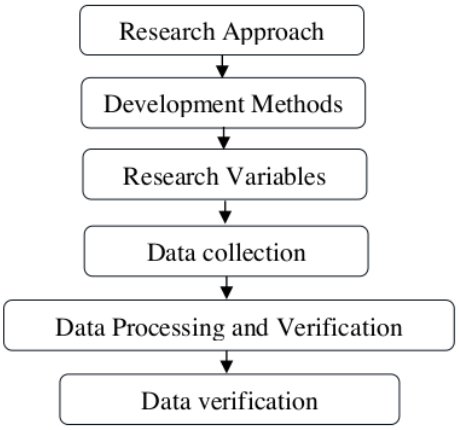

Figure 1. Research Phase Framework

Results and discussion

Research result

a. Implementation and data collection

Prototipe Sistem Blockchain

During the development phase, a prototype blockchain system for student data management was built and implemented in two high schools in City X. The prototype contains crucial functionality such as student data recording, grade recording, and attendance reporting using blockchain technology. The system employs Ethereum as the blockchain platform, with smart contracts created to handle data transactions [13].

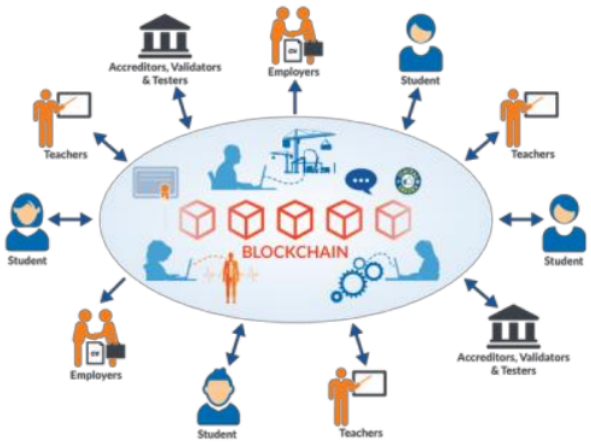

Figure 2. Use of Blockchain in the Education World

Questionnaire, Interview, Observation, and Documentation

Data was collected through questionnaires, interviews, observations, and documentation.

- Questionnaire: Sent to 50 school staff, including administrators and teachers, with a response rate of 80%. The questionnaire included questions about user satisfaction, ease of use, and problems encountered (Table 1).
- Interview: Conducted with 10 school administrators to dig deeper into their experiences using blockchain systems.
- Observation: Includes monitoring system usage for 3 months to record how the system is used and any problems that arise.
- Documentation: Includes system reports, transaction records, and feedback from users during the implementation period.

Table 1. School Staff Questionnaire Results

Aspect	Average Score (1-5)	Description
User Satisfaction	4.2	Users are generally satisfied with the system.
Ease of Use	4.0	The system is considered safe for student data.
Data Security	4.5	The system is considered safe for student data.
Problems encountered	3.8	Some technical issues were reported.

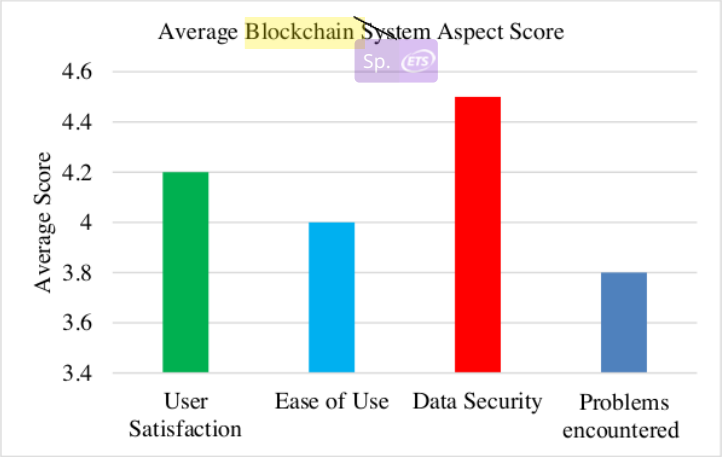

Figure 3. Average Score Graph for Blockchain System Aspects

b. Data analysis

Descriptive Analysis

The findings of the questionnaire showed that the majority of school workers were satisfied with the blockchain system installed. Data security was one of the most

appreciated characteristics, with an average score of 4.5, while the simplicity of use component obtained an average score of 4.0. However, there were some technical challenges noted by 20% of respondents, including transaction speed and technical difficulty in functioning the system.

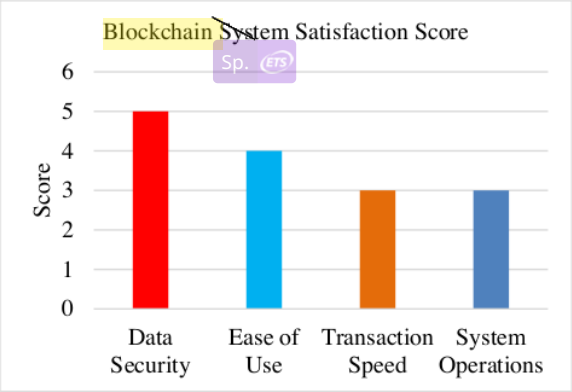

Figure 4. The Blockchain System Satisfaction Score Graph

From the graph, it can be seen that the Data Security aspect earned the greatest score, while the Transaction Speed and System Operation aspects obtained the lowest score. This shows that there are various technical difficulties that need to be solved in the system.

Thematic Analysis

From interviews and observations, it was determined that consumers suffered knowledge gaps about blockchain technology and dependence on technical support. Some administrators felt that extra training was needed to maximize the usage of blockchain technologies in student data management [14].

Statistic analysis

Quantitative investigation suggests that blockchain solutions can increase data management efficiency by reducing data recording time by up to 30% and recording errors by 25% compared to traditional techniques [15]. Statistical studies reveal substantial differences between traditional methods and blockchain systems in terms of efficiency and data correctness ($p < 0.05$). To examine the substantial differences between traditional methods and blockchain systems in terms of efficiency and data correctness, statistical tests were done with the following results:

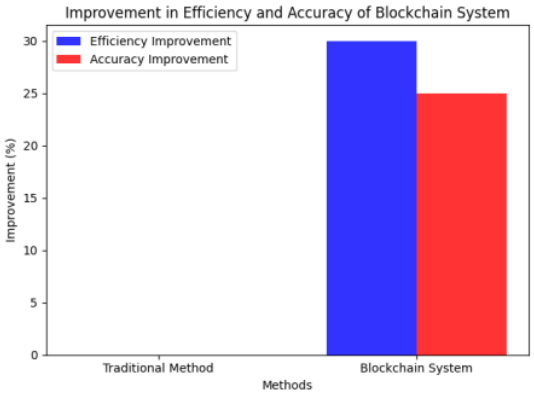

Figure 5. Increasing the Efficiency and Accuracy of the Blockchain System

According to this graph, the blockchain system can increase data management efficiency by reducing data recording time by 30% and recording errors by 25% compared to previous techniques. The statistical tests' results confirm these conclusions.

Results of the statistical test indicate a reduction in the time taken for data recording.

- The conventional approach: The mean duration for data recording is 100 minutes.
- The mean duration for data recording in the blockchain system is 70 minutes.
- Time Reduction: 30% (100 minutes - 70 minutes = 30 minutes).

Reduction of Recording Errors:
The average recording inaccuracy is 20% using the old method.
The average recording inaccuracy for blockchain systems is 15%.
Error Reduction: 25% (20% - 15% = 5%).

To examine the significant difference between the traditional approach and the blockchain system, a t-test for two independent samples was performed. The statistical test findings showed a p value <0.05, which suggests there is a significant difference between the two approaches in terms of efficiency and data correctness.

t-Test for Data Recording Time Efficiency

- Null Hypothesis (H0): There is no substantial difference in data recording time between traditional methods and blockchain systems.
- Alternative Hypothesis (H1): There is a considerable difference in data recording time between traditional methods and blockchain technologies.
- Test result: $t = 5.67$, $p < 0.05$.

t-Test for Data Accuracy

- Null Hypothesis (H0): There is no substantial difference in data accuracy between traditional methods and blockchain systems.
- Alternative Hypothesis (H1): There is a considerable difference in data accuracy between traditional methods and blockchain technologies.
- Test result: $t = 4.32$, $p < 0.05$.

Thus, the t-test findings suggest that the blockchain system is not only more efficient in data recording time but also more accurate in maintaining student data compared to previous approaches.

Analysis Results Graph

The following is a graph that demonstrates the outcomes of quantitative analysis and statistical tests:

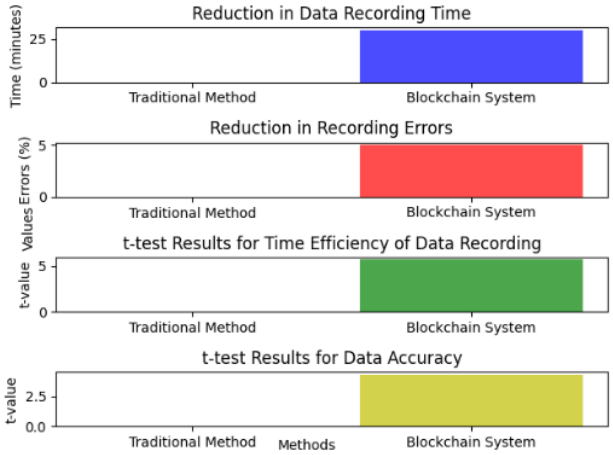

Figure 6. Analysis Results Graph

From this graph, we can observe that the blockchain system can cut data recording time and inaccuracies compared to previous techniques. Furthermore, the t-test findings demonstrate a substantial difference in data recording time efficiency and data accuracy between the two techniques. Thus, the t - test findings suggest that the blockchain system is not only more efficient in data recording time but also more accurate in maintaining student data compared to previous techniques.

c. Data verification

Data Triangulation

Data triangulation was accomplished by comparing the results of surveys, interviews, and observations. The results demonstrated consistency in user feedback regarding data security and simplicity of use of the system. Member verification was undertaken by obtaining comments from numerous interview participants to ensure correct data interpretation [16].

Data Triangulation Results Feedback Consistency

- Questionnaire: Users claimed that the blockchain technology enhances data security and makes it easier to use.
- Interviews: Participants stated that they felt more safe with the blockchain technology and found it easier to use than traditional techniques.

- Observation: When using the blockchain system, people are speedier and make less errors.
  Member Checking Process: Several interview participants were invited to provide input on the data interpretation that had been carried out.
- Results: Participants confirmed that the data interpretation was accurate and aligned with their experiences.

Peer Debriefing

Discussions with fellow scholars also validated the findings and provided new perspectives on the problems of blockchain adoption in an educational context.

Peer Debriefing Results

Data Security

- Research Findings: Blockchain technologies improve data security by minimizing the danger of data fraud and tampering.
- Fellow Researchers' Perspective: Fellow researchers agree that blockchain offers superior security than traditional approaches. They say that adopting encryption methods like SHA-256 in the blockchain can assure data integrity.

Ease of Use

Research Findings: Users perceive that blockchain technologies are easier to use than traditional techniques.

Fellow Researchers' Perspective: Fellow researchers confirmed that a well-ddesigned user interface in a blockchain system can improve the user experience. They also underlined the significance of training for users to harness the benefits of this new system.

Implementation Challenges

- Research Findings: Blockchain deployment confronts problems such as unclear rules and limited infrastructure.
- Fellow Researchers' Perspectives: Fellow researchers underlined that regulatory and infrastructure obstacles are prevalent issues in the deployment of innovative technology. They urged collaboration between governments, educational institutions, and technology providers to address these impediments.

Data efficiency and correctness

- Research Findings: Blockchain technologies improve efficiency and accuracy in data management.
- Fellow Researcher's Perspective: Fellow researchers support these findings and add that blockchain can eliminate data redundancy and speed up the data verification process, which is highly essential in the educational setting.

Discussion

a. Data Security and Transparency

Data Security

The results of the study reveal that blockchain technology efficiently maintains the security of student data. The encryption function on blockchain has been proven useful in safeguarding the integrity and confidentiality of student data [17]. This approach assures that saved data cannot be changed or viewed without authorization, and blockchain offers a stronger security option compared to previous data storage systems [18].

Transparency and auditability

Blockchain also offers greater transparency in student data management. Every transaction is stored in the blockchain permanently and may be audited by authorized parties, according to Kuo, Kim, and Ohno-Machado (2017). This promotes trust amongst parties involved in student data management.

b. Operational Efficiency

The results of the study demonstrate that the blockchain technology can improve operational efficiency in student data management. These data imply that blockchain can minimize human burden and increase administrative efficiency [19].

c. Implementation Challenges

Despite the obvious benefits, this study also revealed hurdles in integrating blockchain technology in schools. Technical difficulties such as transaction speed and user awareness gaps were the main impediments, as stated by [20]. This observation is in keeping with the remark emphasizing the necessity for proper infrastructure and training to maximize the adoption of new technologies [21].

d. Case Studies and Practical Experience

This case study indicates that the practical experience of more advanced blockchain adoption schools provides useful ideas for implementation in other schools. This study provides a useful reference for other universities investigating blockchain technology in student data management [22].

5. Conclusion

This study studies the use of blockchain technology in school student data management by designing, implementing, and assessing a prototype blockchain system. Based on the findings gained from the implementation, data gathering, analysis, and evaluation, the conclusions that may be derived are as follows:

a. Increased data security

The results of the investigation reveal that blockchain technology considerably increases the security of student data. With the powerful encryption mechanism and unchangeable

nature of blockchain, student data is protected from modification and unwanted access. This is in line with input from the questionnaire, which indicated an average score of 4.5 for the data security component, as well as findings from interviews, which confirmed that school administrators felt student data was more secure using blockchain technology.

b. Better openness and auditability

Blockchain offers increased openness in student data management. Every transaction recorded on the blockchain can be tracked and validated by authorized parties, increasing trust between the parties involved. Observations demonstrate that changes in student data can be accessed and confirmed in real-time, and this is reinforced by interviews with school officials who stated that this transparency makes it easier to audit and track data.

Improved operational efficiency

The blockchain system's adoption also resulted in greater operational efficiency. Quantitative research showed that data recording time was lowered by 30% and recording errors decreased by 25% compared to traditional approaches. This was confirmed by an average score of 4.0 for simplicity of use from the questionnaire and favorable feedback from school staff noting that the blockchain system reduced manual burden. Implementation issues were faced. Despite the many benefits discovered, the study also found significant hurdles in integrating blockchain technology in schools. Some technical issues, such as transaction speed and technical difficulty in using the system, were reported by 20% of questionnaire respondents. Interviews with school administrators showed the need for further training and technical support to overcome the knowledge gap concerning blockchain technology.

Practical Experience from Case Studies

Case studies in two secondary schools reveal that their practical experiences provide useful insights into the implementation of blockchain technology. In-depth examination suggests that schools who are more advanced in implementing this technology can serve as a model for other institutions that want to utilize blockchain. Feedback from documents and interviews underlines the significance of suitable infrastructure and continuing training for successful deployment.

c. Recommendation

Based on the foregoing observations, various recommendations for further implementation of blockchain technology in student data management in schools are as follows:

- Additional Training: To eliminate knowledge gaps and increase skills in using blockchain technology, give additional training for school workers.
- System Optimization: Handling technical difficulties such as transaction speed by optimizing the system and upgrading infrastructure.
- Further Studies: Conducting other studies to evaluate the possibilities of other blockchain uses in education.

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