International Journal of Business and Management Invention (IJBMI)
ISSN (Online): 2319 – 8028, ISSN (Print): 2319 – 801X
www.ijbmi.org || Volume 14 Issue 7 || July, 2025 || PP—24-33

Use of blockchain for the secure management of school archives: towards traceability and immutability of academic careers

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SUMMARY
The integration of blockchain into the management of school archives represents a major step forward in the digital transformation of the education sector. This decentralized and transparent technology guarantees the integrity, authenticity, and traceability of students' academic backgrounds. By securing data and providing immutability of school records, blockchain reduces the risk of tampering and improves the management of certifications and diplomas. Thanks to this approach, it becomes possible for students, educational institutions and recruiters to verify academic qualifications internationally in real time and reliably.
However, the management of school archives still poses many challenges, especially in countries such as the Democratic Republic of Congo, where current systems are often inefficient and vulnerable to fraud. Blockchain offers an innovative solution to this problem by offering a more secure and participatory model, where each stakeholder can access information while ensuring its integrity. This system could transform the way school records are stored and verified, building trust and facilitating international recognition of diplomas.

Date of Submission: 09-07-2025 Date of acceptance: 23-07-2025

I. INTODUCTION

The use of blockchain for the management of school archives represents a major advance in the field of education and technology in the Democratic Republic of Congo.

Blockchain, known for its ability to record data in a transparent and decentralized manner, offers a reliable solution for managing academic pathways.[1] By integrating this technology into the storage of school data, it becomes possible to guarantee the integrity of records, thus reducing the risk of falsification or manipulation of information.[2] It also allows for better management of certifications and diplomas, ensuring that they are both authentic and verifiable at all times.[3]

The management of school archives is a crucial issue to guarantee the traceability and authenticity of academic careers. With the rise of digital technologies, blockchain is emerging as a promising solution for securing this sensitive data. By providing a decentralized and immutable structure, blockchain can revolutionize the way educational institutions manage and verify school records.

Traceability is one of the main advantages of a blockchain application in this field. Every step of the academic journey, from enrollment to graduation, can be tracked and verified in real-time. [4] This transparency benefits not only students, who have secure access to their academic history, but also educational institutions and academic authorities, who can validate the information quickly and efficiently. It also facilitates the international recognition of diplomas, making authentication processes more uniform and reliable.

Data immutability is another key feature of blockchain. Once information is recorded in the chain, it cannot be changed or deleted, thus ensuring the durability and integrity of school records. [5] This feature is especially valuable in education systems where data management can be complex and error-prone. By adopting this technology, educational institutions are building confidence in their processes and providing students with a secure way to manage and showcase their academic achievements throughout their lives.

1. State of the question

The management of school archives has traditionally relied on centralized systems, which are often vulnerable to manipulation and data loss. Current solutions lack transparency and security, which poses major challenges in terms of reliability and verification of academic information. Blockchain, as a distributed ledger technology, offers an innovative alternative by ensuring data integrity and traceability

2. Problematic

The management of school archives in the Democratic Republic of Congo (DRC) presents many structural and technical challenges. The lack of modern management systems, especially digital ones, increases the risk of loss and falsification of academic documents. Currently, archives are mostly managed manually with paper media, making them vulnerable to physical damage like fires or floods. These problems lead to delays in the issuance of transcripts and diplomas, and make it difficult to verify students' academic backgrounds, both nationally and internationally [6].

The infrastructures dedicated to the management of archives are often inadequate, especially in rural schools. The preservation of documents is poorly ensured, and the archive rooms are not secured, thus exposing the data to the risk of fraudulent manipulation or deterioration. In addition, the administrative staff responsible for this management are generally not trained in modern records management, which leads to human error in the processing and classification of information. As a result, critical documents, such as diplomas and transcripts, are often lost or mismanaged, undermining the transparency and reliability of academic processes.

The problem is amplified by the scarcity of financial resources to improve school records management systems. This lack of funding prevents the adoption of technological solutions such as the digitization of archives or the use of dedicated software, which could speed up and secure administrative processes.

Faced with these challenges, the use of advanced technologies such as blockchain appears to be a potential solution to improve the management of school archives. Blockchain, with its characteristics of immutability, traceability, and data security, could ensure that academic documents are not lost or tampered with. It would also allow faster and more reliable access to information, reducing the risk of falsification and ensuring long-term retention of school records.

However, the implementation of blockchain in this sector presents several technical and organizational challenges. On the one hand, technical barriers will have to be overcome, especially in terms of IT infrastructure and connectivity, especially in rural areas. On the other hand, there are organisational challenges: the training of administrative staff in new technologies and the acceptance of change by institutions accustomed to traditional systems are major obstacles to this transition. The financial aspect also remains a significant barrier, as the cost of installing and maintaining these modern management systems is high for institutions that are often underfunded.

- ✓ **How can blockchain be used to improve the secure management of school archives, ensuring the traceability and immutability of academic pathways?**
- ✓ **What are the technical and organizational challenges to be overcome for the implementation of this technology in the education sector?**

Based on this questioning, we would like to demonstrate the feasibility of this blockchain integration for a better management of school archives in this research.

3. Methodology

To respond effectively to the problem, a structured and progressive methodological approach will be implemented, in five key steps:

1. Literature review:

An in-depth analysis of existing research will be carried out to understand the use of blockchain in different sectors, with a particular focus on its applications in the field of education. This step aims to establish a solid theoretical foundation by identifying the advantages and limitations of blockchain in academic data management.

2. Case Study:

Several pilot projects and initiatives where blockchain has been integrated into the management of school archives will be studied. The objective is to identify best practices, success factors, and lessons learned from these experiences in order to inform the study and adapt these practices to the specific context of the DRC.

3. Surveys and interviews:

Qualitative data will be collected through surveys and interviews with key stakeholders, such as school administrators, blockchain experts, and students. These discussions will help to understand the perceptions, expectations and main challenges related to the adoption of blockchain for the management of school archives, as well as to assess the feasibility and acceptability of this technology.

4. Comparative analysis:

A comparative evaluation will be conducted between traditional records management systems and blockchain-based solutions. This analysis will focus on criteria such as data security, traceability, efficiency, implementation costs, and long-term performance. This will help quantify the potential benefits of blockchain compared to current methods.

5. Prototyping and testing:

A prototype of a school records management system using blockchain technology will be developed. This prototype will undergo rigorous testing to assess its effectiveness, security, and robustness in academic data management. The results of these tests will provide valuable insights into the adaptability of the solution in a real-world school environment.

This methodology will provide a comprehensive and well-documented analysis of the possibilities of integrating blockchain into the management of school archives in the DRC. It will result in practical and specific recommendations on the implementation of this technology in the education sector, taking into account the technical, organizational and financial challenges.

4. Research background

a. The management and problems of school archiving in the school environment in the DRC

The context of school archives management in the Democratic Republic of Congo (DRC) is characterized by major challenges that affect the integrity and efficiency of the education system. Traditional academic archive management still relies heavily on paper, exposing documents to significant risks of physical deterioration, loss, or forgery. According to Ngoma-Binda (2016), school infrastructure in the DRC is often insufficient and does not allow for optimal preservation of administrative documents, thus exacerbating the difficulties related to the management of academic data.

In addition, the digitization of school archives in the DRC is still very limited, especially in rural areas where access to information technology remains precarious. Studies such as the one by Masirika and Kataliko (2021) show that the digitization of archives could play a key role in securing academic records and improving transparency in credential verification processes. However, this solution is not widely adopted due to low financial resources and lack of technological infrastructure.

The lack of centralization of school archives is another major obstacle. Data is generally dispersed at the level of individual institutions, without any real national coordination, which makes it difficult to trace academic documents (Mukendi, 2019). This lack of centralization is exacerbated by an inadequate legal framework and insufficient training of administrative staff, which prevents the establishment of a unified and effective school record system.

Some recent reforms in African countries such as Kenya and Nigeria offer interesting examples for the DRC. For example, these countries have invested in the digitization of school archives, with promising results in terms of reducing graduation times and improving transparency (Mbwana, 2020). These examples show that modernizing archives management is possible, but requires significant investments in infrastructure, training, and the adoption of new technologies such as blockchain (Mbalanda, 2021).

In sum, the management of school archives in the DRC faces profound challenges that affect not only the quality of education, but also the efficiency of administrative processes. Digitization and centralization of data are possible solutions to improve the transparency and reliability of the education system, but their implementation requires considerable political will and resources.

b. Blockchain in the management of school archives

The current context of school archives management in the Democratic Republic of Congo (DRC) is marked by considerable challenges, mainly related to the use of an archaic system based on paper media. This management method leads to loss, falsification and difficulty in accessing official documents (Ngoma-Binda, 2016). Faced with these challenges, blockchain technology is emerging as a promising solution to secure and modernize the management of academic archives. Blockchain, known for its ability to ensure data immutability, traceability, and security, could transform the management of school archives in the DRC by ensuring reliable retention and rapid verification of academic records (Mbalanda, 2021).

One of the main advantages of blockchain is its ability to create a decentralized, tamper-proof ledger of data. In a context where school archives are often subject to manipulation, this technology could solve the problems of falsification of diplomas and transcripts. A study by Masirika and Kataliko (2021) shows that blockchain could offer full traceability of academic documents, making it possible to verify the authenticity of records at any time, and instantaneously. This traceability is essential in the DRC, where manual procedures are often slow and unreliable (Mukendi, 2019).

Data security is another key benefit of blockchain. The technology's ability to protect sensitive information from tampering ensures the reliability of archives, while facilitating their remote access by

academic authorities and students (Mbwana, 2020). This would not only reduce the time taken to issue critical documents, but also improve the transparency of academic processes, an aspect that is often criticized in the DRC (Mbalanda, 2021).

Finally, the implementation of blockchain could come with cost reductions in the long term. While the initial investment to adopt this technology may seem high, the savings generated by reducing costs related to manual management, errors, and fraud would be significant (Mukendi, 2019).

In conclusion, blockchain represents an innovative and viable solution to meet the multiple challenges of managing school archives in the DRC. It not only provides better security for academic data, but also improves process efficiency and increases transparency in the issuance of academic documents.

5. Design of a participatory school archive management model

The design of a participatory school records management model, integrating blockchain and other modern technologies, is based on three main elements: the **design framework**, the **design science,** and the **artifact**. Each of these elements helps structure the solution in a way that ensures the security, traceability and transparency of school archives while allowing for the active participation of various stakeholders.

1) Design Framework

The **design framework** is used to define the principles, objectives and ground rules on which the participatory model is based. The aim here is to actively involve stakeholders (school administrators, teachers, students, parents and education authorities) in the archive management process. This framework should be based on:

- **Collaborative participation** : The participatory element is central. Stakeholders should have controlled access to the archive through an intuitive user interface. This includes a role-based management system (RBAC), where each actor has a level of access tailored to their responsibilities.
- **Data security** : The model would rely on blockchain to ensure the immutability of data and prevent any falsification of academic documents. Blockchain helps ensure that every change or access to the archive is permanently and transparently recorded.
- **Digital centralization and decision-making decentralization** : Although data must be centralized in a digital ledger, the management and validation of inputs will be decentralized, allowing different actors to validate the information before it is recorded.

1.1. Design Framework Diagram

The **design framework** would be represented by a hierarchical structure or flow diagram in four major interconnected parts, including key players and essential processes.

a. General flow diagram

This diagram gives an overview of the system, showing the main inputs and their interactions.

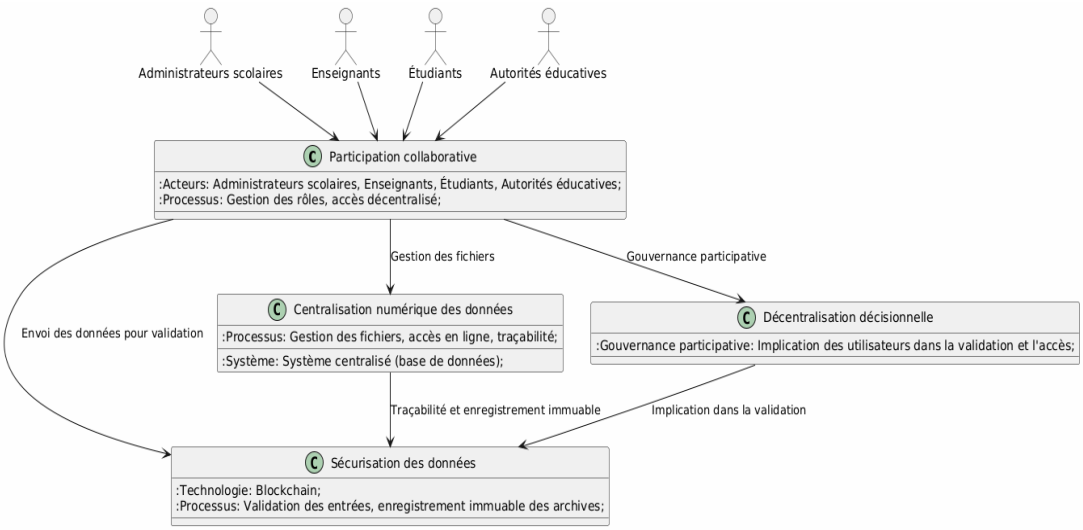

Figure 1:d flow of information

b. Sequence diagram

This diagram details the steps involved in validating a new entry into the system, highlighting the role of the blockchain.

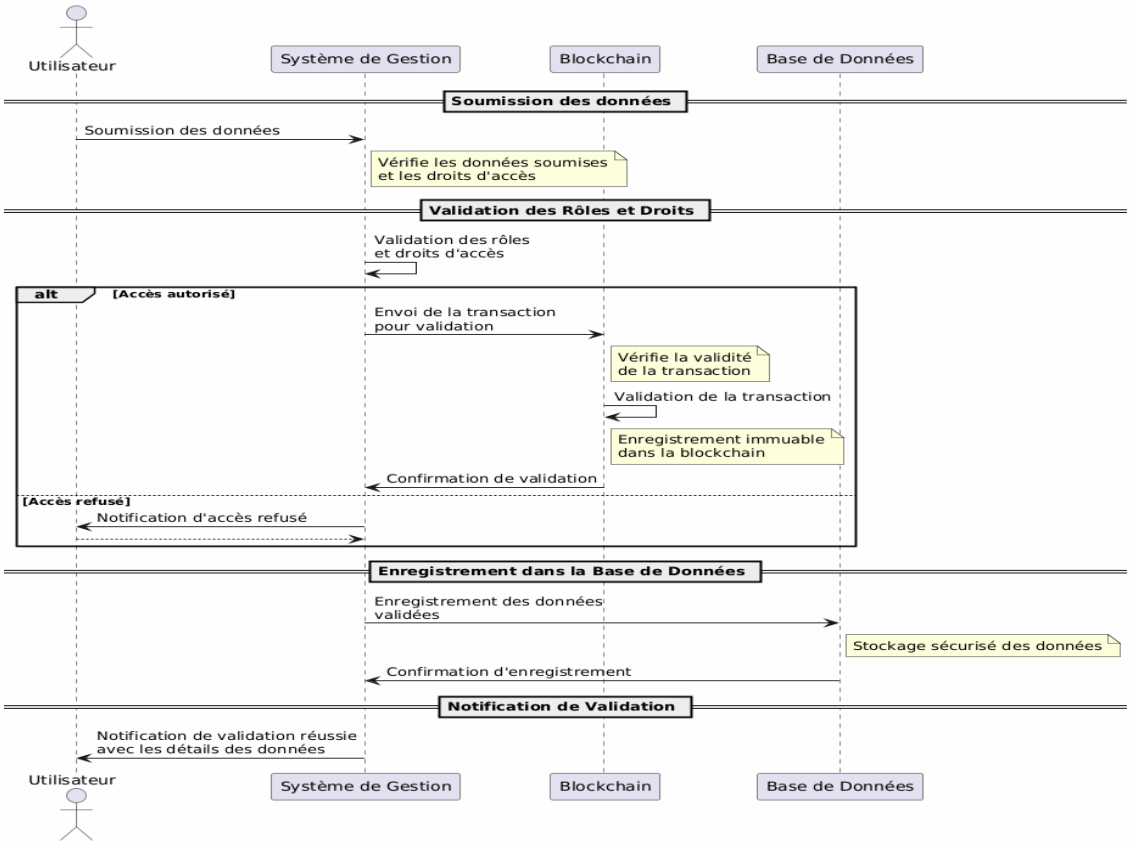

Figure 2: sequence diagram

c. Use Case Diagram

This diagram describes the different data access scenarios, depending on the user's role and the permissions granted.

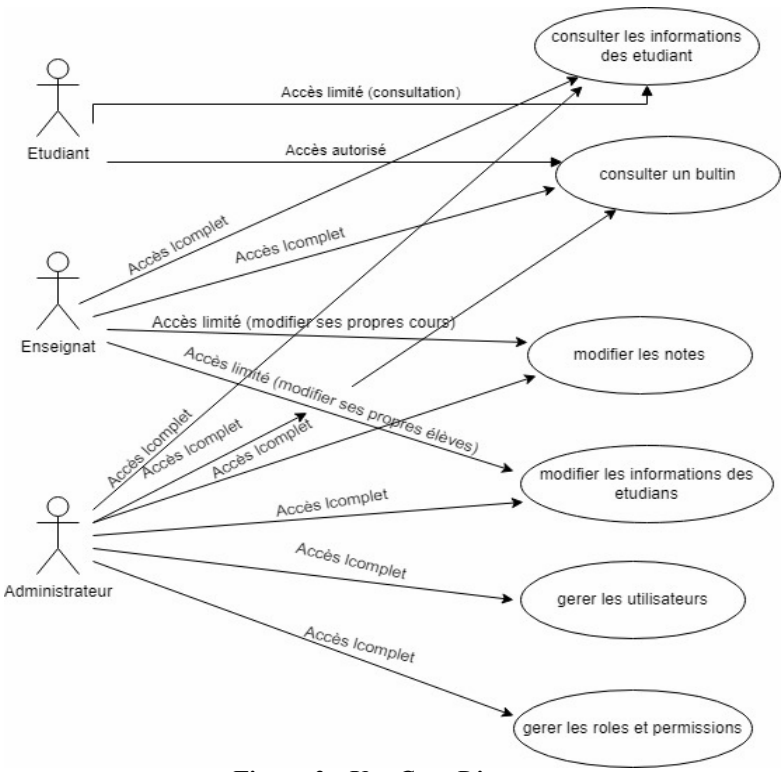

Figure 3 : Use Case Diagram

2) Design Science

Design Science aims to propose a pragmatic solution that meets the needs identified in the design framework based on empirical research. This includes:

- **Identification of needs** : The process begins with an in-depth analysis of the needs of schools in terms of archive management (security, accessibility, traceability). Technical and institutional limitations should also be considered, such as limited access to technology in some rural areas.
- **Prototyping and testing** : A prototype solution should be designed, with regular iterations based on feedback from end users (the various stakeholders). Testing should include simulations of use cases and potential attacks against archives to assess the robustness of the solution.
- **Continuous improvement** : The business model must remain flexible and scalable in order to adapt to new challenges and the evolution of educational and blockchain technologies. User feedback will contribute to the continuous improvement of the system.

2.1. **Schematic for Design Science**

For design **science**, a five-step model based on the **Design Science Research (DSR)** method could be illustrated by a pie chart or an iterative process, with feedback at each step:

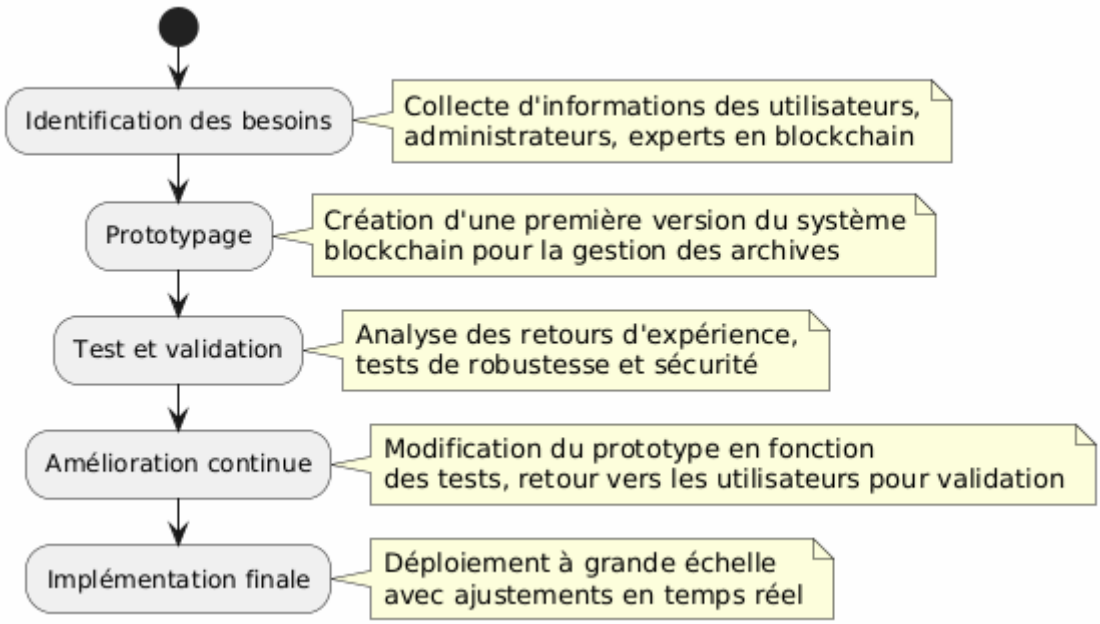

Figure 4:d esign science

3) Artifact

The **artifact** is the tangible result of the design process. In this participatory school archives management model, the artifact is an **integrated blockchain system**, designed to secure and manage academic archives in a transparent and participatory way. The main components of this artifact are:

- **Blockchain-based archive management system** : This system is based on a distributed ledger, where each transaction (access, modification, validation of a document) is recorded in a transparent way. This ensures the integrity of the archive while ensuring immutable monitoring of activities.
- **Participatory user interface** : Users (administrators, teachers, students, etc.) will be able to access documents through an intuitive web or mobile interface. The interface will also have to make it possible to submit requests for modification or validation of documents, while respecting access rights according to the assigned roles.
- **Smart contracts** : These smart contracts will be used to automate processes related to document validation, access management, and recording of critical information, ensuring that the pre-established conditions for each action are met before execution.
- **Notification and alert system** : To ensure the responsiveness of the various stakeholders, the system could include automated notifications to inform users of the actions to be taken (document validation, access to archives, etc.).

3.1. **Artifact (Prototype)**

The **integrated blockchain system** could be illustrated by a diagram of technical components showing the interaction between:

- **Distributed database** (Blockchain Ledger).
- **Smart Contracts** to automate access management.
- **User interface** (online portal accessible to the various stakeholders).
- **Notification mechanism** to alert users to required actions.

This participatory management model is designed to meet the current challenges of school archives management in the DRC, building on the advantages offered by blockchain in terms of data security and immutability. It also incorporates a collaborative approach that ensures the involvement of stakeholders in the education sector while ensuring greater transparency and traceability of processes related to archive management.

6. Validation of the management model

To validate a blockchain-based school records management model, it is important to structure the process around three key elements: **methodology**, **experimentation**, and **projected outcomes**. Each step helps to confirm the feasibility and effectiveness of the proposed model in a real-world environment.

1. Methodology

The model validation methodology involves several strategic steps, from data collection to analysis of the results. Here's a detailed approach:

- **Data collection** :
  - Surveys or interviews will be conducted with various stakeholders, such as school administrators, teachers, students, and blockchain experts. This data will help to understand their expectations and concerns about school archiving.
  - The study of existing archival systems (paper and digital) will be carried out to identify their shortcomings in relation to the criteria of security, transparency and cost.
- **Prototyping** :
  - A working prototype of the blockchain-based system will be developed and tested in several pilot institutions.
  - This prototype will include the key features of the model, such as traceability of diplomas, security of archives, and online accessibility.
- **Performance indicators** :
  - Specific criteria will be used to evaluate the performance of the prototype, including **security** (protection against tampering), **traceability** (tracking changes and access), **cost** (savings compared to current systems), and **user satisfaction**.

2. Experimentation

The experiment aims to test the model in a controlled environment and assess its feasibility and effectiveness. The process includes:

- **Selection of pilot schools** :
  - A sample of schools or universities in the DRC will be selected to implement the archive management system. Institutions will be chosen based on their size, technological infrastructure, and current archiving practices.
- **Prototype deployment** :
  - The model will be implemented in the selected establishments. Regular follow-up will be provided to observe users' interaction with the system and resolve any issues encountered.
  - School administrators and students will be trained on how to use the blockchain platform to ensure effective adoption.
- **Collection of usage data** :
  - During the experimentation period, data on the use of the system will be collected (access time to archives, frequency of errors, security incidents, etc.).
  - Qualitative feedback will also be obtained through questionnaires and interviews to measure user satisfaction and their perception of security and transparency.

3. Projected results

The expected results of the experiment should confirm or refute the effectiveness of the model. Below are the projected concrete results:

- **Improved security** :
  - The blockchain system should prevent any falsification of academic documents, by recording each change in an immutable ledger. This will be validated by reducing or eliminating cases of document fraud in the pilot institutions.

- **Increased traceability** :
  - Archived documents can be traced, with each consultation or modification recorded in the blockchain. This allows educational authorities and students to verify the authenticity of diplomas without additional intervention.
- **Reduction of management costs** :
  - By replacing manual or semi-digital systems with a blockchain solution, the costs associated with archive management (printing, storage, physical security) should be reduced. A comparative financial report will be generated to validate this aspect.
- **Better accessibility of archives** :
  - The digital archive will be accessible quickly and securely, both by students and administrators. This should reduce the time it takes to issue diplomas or transcripts.
- **User satisfaction** :
  - Users (administrators, teachers, students) should report an improvement in archive management and retrieval. Satisfaction will be measured through post-implementation surveys.

This validation is based on a **rigorous methodology**, combined with **controlled experimentation** to test the blockchain artifact under real-world conditions. The **projected results** confirm the model's contribution in terms of security, transparency and cost reduction, while improving the management of school archives in contexts where fraud and administrative slowness are frequent.

II. DISCUSS

The present research focused on the design, experimentation and validation of a blockchain-based school archives management model in the Democratic Republic of Congo (DRC). The results obtained revealed several important points, both theoretically and practically.

1. Findings

The results of this study show that the integration of blockchain into the management of school archives has substantial benefits in terms of security, transparency, and traceability of academic documents. In particular:

- **Data security** : The blockchain system has eliminated the risk of falsification of records, thanks to the immutable nature of the records. Feedback from administrators and students confirmed greater confidence in the integrity of academic documents, such as diplomas and transcripts.
- **Improved access to archives** : Tests conducted at the pilot institutions showed that users could access archives more quickly and efficiently. It has also reduced delays in the issuance of academic documents.
- **Cost reduction** : Automation and digitization via blockchain have significantly reduced the costs associated with manual archive management (such as printing and storage). Schools have thus been able to save on human and material resources.

These results confirm the effectiveness of a blockchain system in the education sector, especially in a context like that of the DRC where archiving practices are still mainly paper-based, with systems often vulnerable to fraud and human error.

2. Theoretical implications

From a theoretical point of view, this research contributes to enriching the work on the application of blockchain in non-financial sectors. While blockchain is well known for its uses in cryptocurrencies, this study shows that it can also be a powerful tool for managing academic archives. Several theoretical points emerge from this research:

- **Data Security and Transparency Theory** : The use of blockchain as a technology to ensure transparency and immutability of information is an enrichment for data security theories. The management of academic archives thus becomes a new field of application for existing theories on secure information management.
- **Contributions to decentralized management** : Blockchain is introducing elements of decentralized management into schools, which can redefine theories about data management in the public and education sector. This model aligns with theories of **user empowerment**, allowing them to verify and access their information themselves, without intermediaries.

3. Practical implications

The practical implications of this research are significant, especially in contexts where traditional records management systems are ineffective:

- **Improved management of school archives** : This blockchain model can be implemented in schools and universities in the DRC to improve the management of school archives, providing faster access, full traceability of documents and protection against fraud.
- **Cost reduction and administrative simplification** : By automating a large part of the archiving process, educational institutions will not only be able to reduce administrative costs, but also reduce the workload associated with manual archive management.
- **Standardization of management practices** : The introduction of blockchain may also bring some standardization in the management of academic archives across the country. This system could be used in all educational institutions to ensure uniformity of procedures and data security.
- **Faster issuance of diplomas and transcripts** : The frequently observed delays in the issuance of academic documents can be reduced with an automated blockchain-based system.

In summary, the validation of the blockchain-based school archives management model in the DRC has shown promising results, both in terms of data security and operational efficiency. This model could be a lever for modernizing the management of academic archives, with important implications for educational institutions, students, and academic authorities. The theoretical and practical contributions of this research pave the way for a new way of conceiving the management of school information in contexts where security and transparency are major concerns.

III. CONCLUSION & LIMITATIONS

This research explored the design and validation of a blockchain-based school archives management model in the Democratic Republic of Congo (DRC). The main objective was to address the critical challenges of inefficient management, fraud, and lack of transparency in the management of academic documents by offering a secure, traceable, and reliable system. The results obtained show that blockchain can indeed offer innovative solutions, guaranteeing archive security, improved transparency, as well as cost reduction. Feedback from the pilot institutions confirms a general satisfaction of users and greater efficiency in the management of academic data.

The contributions of this study are both theoretical and practical. From a theoretical point of view, it reinforces discussions on the use of blockchain in non-financial sectors, and more specifically in the management of academic data. In practice, it offers a modernized and standardized approach for educational institutions, capable of improving security and access to critical documents such as diplomas and transcripts.

Research Limitations

Despite its important contributions, this research has some limitations:

1. Limited geographic scope: Testing was conducted in a limited number of facilities in the DRC. It would be necessary to extend the experiment to other provinces, or even to international contexts, to generalize the results.
2. Technological infrastructure: Blockchain implementation requires strong digital infrastructure, which is not always the case in all schools in the DRC, especially in rural areas. Large-scale success will therefore depend on improving connectivity and Internet access infrastructure.
3. Stakeholder adoption: While the results show positive user acceptance, the transition from a traditional to a blockchain-based system may encounter resistance in some institutions, especially due to technological complexity and changes in administrative processes.
4. High upfront cost: Blockchain deployment can involve relatively high upfront costs, related to acquiring the necessary infrastructure, training staff, and integrating the system into existing structures.
5. Legal and regulatory framework: The implementation of blockchain in the management of school archives requires a clear legal framework to guarantee the authenticity of digital documents for legal purposes, particularly in the case of international diploma validation.

Prospects

To overcome these limitations, further research is needed to explore:

- The adaptability of the model in various educational contexts,
- Solutions for updating digital infrastructure in the DRC,
- The establishment of an appropriate legal framework to support the use of blockchain in education.

Thus, a large-scale implementation will require strategic technological and regulatory support, while ensuring gradual adoption by users

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