Journal of Applied Science, Engineering, Technology, and Education *ISSN: 2685-0591 (online)*
Vol. 8 No. 2 (2026)
https://doi.org/10.35877/454RI.asci4622

A Blockchain-Based Framework for Decentralized Academic Credentialing: Designing a Secure Architecture for Indonesia

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Abstract

Indonesia's education system is dealing with issues worldwide, such as fake diplomas, poor administration, fragmentation of data, and a misalignment of curriculum and job market demands. The centralised data system of the Indonesian government is hackable/ alterable. This study aims to explore and evaluate global blockchain technology's relevance to and challenges in the Indonesian education system. This study applied the Literature Review methodology with the use of the PRISMA framework. Out of the numerous studies available, 57 were chosen from the Scopus database from 2016 to 2026. The results of the study indicate that blockchain technology offers education systems a solution to the problem of storage, from the perspective of security, transparency, and immutability. Furthermore, the problem of diploma fraud and administrative inefficacy in systems can be solved through the decentralised verification of blockchain. Adopting this technology is still a problem, in that educational data remains unregulated and the internet is poorly available; the large storage capacity of the blockchain system is a problem too. Overall, blockchain technology has the possible prospects of transforming the Indonesian education system to be more inclusive, accountable and secure. To achieve this, unified efforts of all stakeholders is essential

Keywords: Education Landscape, Blockchain, Prisma, Cybersecurity, Decentralized systems

Received: 29 January 2026 Revised: 2 May 2026 Published: 31 August 2026

1. Introduction

Educators help students acquire skills necessary for specific jobs (or for continuing education) (Kontzinos et al., 2024). The Indonesian education system faces challenges such as uneven access to education that is good, clear, and fair, as a result of poor administration, credentialing issues, unequal access to educational resources, and opaque education system funding. One of the most innovative methods to solve issues with education systems around the globe is the use of blockchain technology (Alammary et al., 2019).

The use of blockchain technology inthe education sector has significant room for growth and improvement. This research outlines the advantages and disadvantages of blockchain technology in education, which will aid future research. In education, the establishment of trust is fundamental and blockchain technology facilitates that trust in the transactional relationships amongst the various stakeholders in higher education. Applying blockchain tech to verify digital records could potential increase trust in education and educational systems (Lizcano et al., 2019). Furthermore, how blockchain can verify digital records to show the usefulness of this technology in a digital world (Jirgensons & Kapenieks, 2018). The more time passes, the more blockchain show how it can transform management education by improving data management to be better, more effective and secure (Bhaskar et al., 2021; Raimundo & Rosário, 2021).

Considering problems of micro-authentication systems on blockchains in various countries, in this case, Indonesia, it is interesting and useful to explore how blockchain in education can be the first step to building a more inclusive and sustainable education system of the future (Alsobhi et al., 2023; Samala et al., 2024). Blockchain technology is useful for managing data and resources, online testing, and verifying educational credentials (Chen et al., 2023). It has been easier and more effective to manage academic records and certificates, making transparency and efficiency

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improvements (Raimundo & Rosário, 2021). It allows more students to be involved and enhances trust in the verification (Kwok & Treiblmaier, 2022). The combination of blockchain with other technologies such as artificial intelligence and the Internet of Things, will most likely result in innovations in education (Chen et al., 2023; Page et al., 2021).

This study engages with challenges of identity as they arise in the Indonesian education system and examines the possible use of blockchain technology. The study has the following objectives:

a. Determine the major constraints in the education system in Indonesia.
b. Examine the recent innovations in blockchain technology across the globe in the education sector.
c. Assess the suitability of blockchain in terms its possible benefits and address the challenges that may arise in the context of Indonesia

The study also attempts to assess the possible technical constraints of blockchain within the context of Indonesia and examines the possible benefits and challenges to the implementation. The study also seeks to help policymakers, educators, and the IT industry people in Indonesia to understand better the use of blockchain in education. The final aim is to assist in the development of systems that respond to the needs of the Indonesian education system, to make education more accessible, more efficient and more immutability.

2. Methods

This study has reviewed the literature concerning the application of blockchain in the field of education. The methods utilized are in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). PRISMA provides an examination framework to assist in enhancing reporting quality and the systematic methodology of reviews. It has been implemented in numerous disciplines.

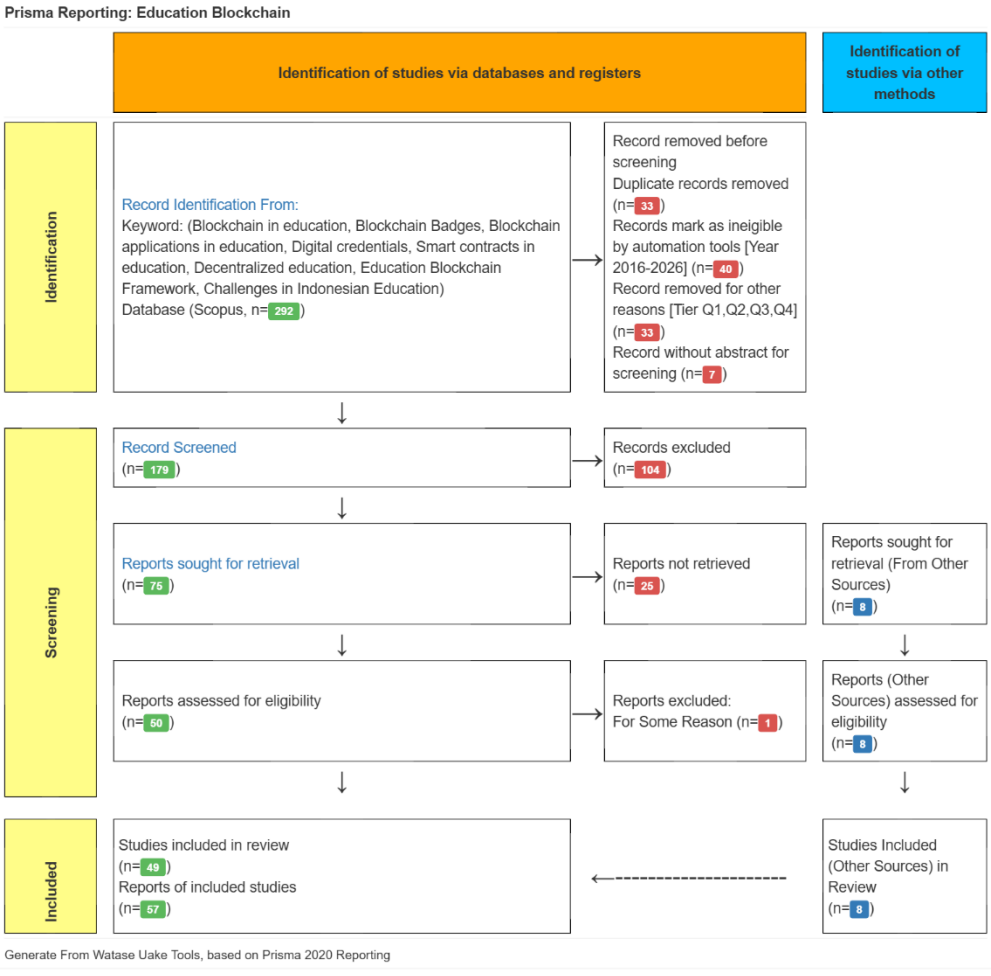

Figure 1. Prisma Diagram of Screening and Reporting

2.1. Stage Identification

The identification process article starts with identifying coverage research by conducting a review limited to relevant and contemporary articles. Three questions guide SLR research:

a. What are the most significant challenges in Indonesia's education that can be overcome with blockchain technology?
b. What blockchain-based solutions have been proposed or implemented globally to address challenges like secure credentials, transparent funding, and inclusive learning, and how relevant are these solutions in the Indonesian context?
c. What are the potential benefits, obstacles, and impacts in the long term from implementing blockchain technology in the Indonesian education system, in particular in matters of secure credentials, transparent funding, and inclusive learning?

These questions provide a clear focus for reviewing and guiding relevant literature.

2.2. Data collection

Data taken from the Scopus database focused on publications relevant to the theme. Research that focuses on blockchain applications in education globally, as well as locally, with a special discussion of the Indonesian context. Relevant publications from 2016 to 2026 include various aspects of blockchain in education, such as applications, challenges, and frameworks. Stage data collection is done by searching using keywords specific to the research topic, such as:

Table 1. Topic keywords study

No.	Keyword
1	Blockchain in education
2	Blockchain Badges
3	Blockchain applications in education
4	Digital credentials
5	Smart contracts in education
6	Decentralized education
7	Education Blockchain Framework
8	Challenges in Indonesian Education

The database used in this search is Scopus, which was selected for its advantages in providing scientific article quality through a strict indexing process. Scopus was chosen as the primary database to ensure the validity and relevance of articles obtained.

2.3. Search and Filtering Process

A search process article starting with a search query in Scopus obtained 292 articles. Next, do Deletion Duplication. A total of 33 articles were deleted because they are duplicates. Forty articles were removed because they did not fit the topic. the tool automatically marked them as unfit (2016-2026). This also includes language, study type, document type mismatch, year of publication criteria, and full text unavailability. Thirty-three articles were deleted for other reasons, including journal tiers (Q1, Q2, Q3, Q4). Seven articles were deleted because it does not have abstracts to be filtered. After the filtering process, the remaining articles to be screened are 179. Of these, 104 articles were excluded because they were not relevant, and 75 reports were sought to be retrieved. However, 25 reports were not retrieved. Finally, 50 reports were assessed for eligibility, of which 1 were excluded for specific reasons. Finally, 49 studies were included in the review. Plus, eight articles from other sources. A total of 57 studies were included. Figure 1 shows the results from the PRISMA process (Identification, Screening, and Inclusion).

2.4. Data Extraction and Synthesis

In maintaining uniformity, models of a standard nature are employed during data extraction. After being collected, data is assessed using both qualitative and structural methodologies to fulfill the study questions. Patterns and themes are analyzed and identified, concerning the issues, solutions, and effects of using blockchain in Indonesia's educational system.

2.5. Report

The aforementioned technologies offer a solid and systematically organized study of the available literature concerning the application of blockchain in the educational sector, especially in Indonesia. This study operates within the boundaries of the PRISMA framework and offers a comprehensive synthesis of the prior studies, addressing the posed research questions, and broadening the understanding of the application of blockchain technology in education

3. Results and Discussion

3.1. Result

The analysis reveals that most of the research works regarding blockchain technology in education, as in the majority of cases, used different types of research approaches, either qualitative, quantitative, or mixed. Out of the total number of 57 research works, 33 used qualitative approaches, 20 used quantitative approaches, and 4 used mixed approaches. For example, qualitative approaches in some instances comprise of systematic literature reviews, and even content analysis, which in most cases aid researchers in understanding the problem, opportunities, and challenges pertaining the use of blockchain in education (Palma et al., 2019; Rani et al., 2024). On the other hand, quantitative approaches, such as adoption surveys and even statistical analysis, provide a number of data concerning the use of blockchain and even its effectiveness in the field of education (Bhatia & Bhasin, 2023; Samala et al., 2024). These data points lead towards the conclusion that there seems to be a tendency towards advocacy of qualitative research works, but in most cases, there exists a void which subsequent research works could fulfil, pertaining to investigations of the impacts of blockchain technology in education. Most of the time, researchers mention empirical evidence pertaining to, privacy, security, and even acceptance, which in most cases, accompany the use of blockchain (Pongnumkul et al., 2021). When it comes to the number of citations falling towards a particular research work, most of the time, qualitatively oriented research tends to attract a larger number of citations, in some case studies a citation number of 200 has been reached (Alammary et al., 2019; Kontzinos et al., 2024).

Of the 57 articles examined, reviews of literature appear to have been the most dominant method of data collection, with 30 and 20 articles in each of these categories, inclusive of both review and qualitative study types. Out of the 50 articles reviewed, 28 (56%) were published in Q1 and 15 (30%) in Q2 journals. Such interest among researchers and editors of high-ranking journals illustrates the value and contribution these publications are making to the field. In the context of the ongoing problems and the potential of the blockchain to transform the educational process, it is important to emphasize the developed and emerging possibilities of the blockchain to create flexible and open educational systems.

The most research studies regarding the application of blockchain within the educational context are from the year 2022 documenting 12 such studies. This suggests that the application of blockchain in education is becoming more popular among researchers in the areas of safeguarding data and verifying educational credentials (Bathula et al., 2022; Chen et al., 2023). Citing the works of Lezcano (Lizcano et al., 2019) and Bhaskar (Bhaskar et al., 2021) is notable because they have received 194 and 147 citations respectively, which suggests that they have made significant contributions to the field of education and the application of blockchain in to it.

In the context of education, factors influencing the adoption of blockchain technology include perceived ease of use, how well it performs, how aware the community is of it, and organizational support. Blockchain technology has the ability to completely change how academic data is managed and could also have real-world effects on creating policy. The application of blockchain technology in education needs to be improved from a number of problems or limitations, so that it can be fully used in the education system (Chawla et al., 2024).

In a decentralized education system, encouraging collaboration between educational institutions is key to overcoming the challenges of limited resources, uneven distribution of quality, and the need for specialized research directed in several fields (Greany et al., 2025). The implementation of blockchain technology in deep learning offers plenty of challenges, but also provides great possibilities for research in the future. There is a need for more research on this technology (the blockchain) from a more wide-ranging view and for the overcoming of the barriers in order to access the potential of blockchain technology to improve the quality of education (Samala et al., 2024). Additionally, future researchers are encouraged to use a combination of multiple theories and methods to find solutions that are more comprehensive and applicable solution.

3.1.1. Determine the major constraints in the education system in Indonesia.

Continuous digitalization increases requests for convenience, certainty, and security, highlighting the need for innovative, efficient, and safe education. This study proposes a framework to be implemented in an integrated education system using blockchain technology in Indonesia's education system. The proposed integrated education system serves as a medium for enforcing the rights of constitutional Indonesian citizens by increasing safety, efficiency, and quality of educational services. Figure 2 is an overview of the educational process flow in Indonesia.

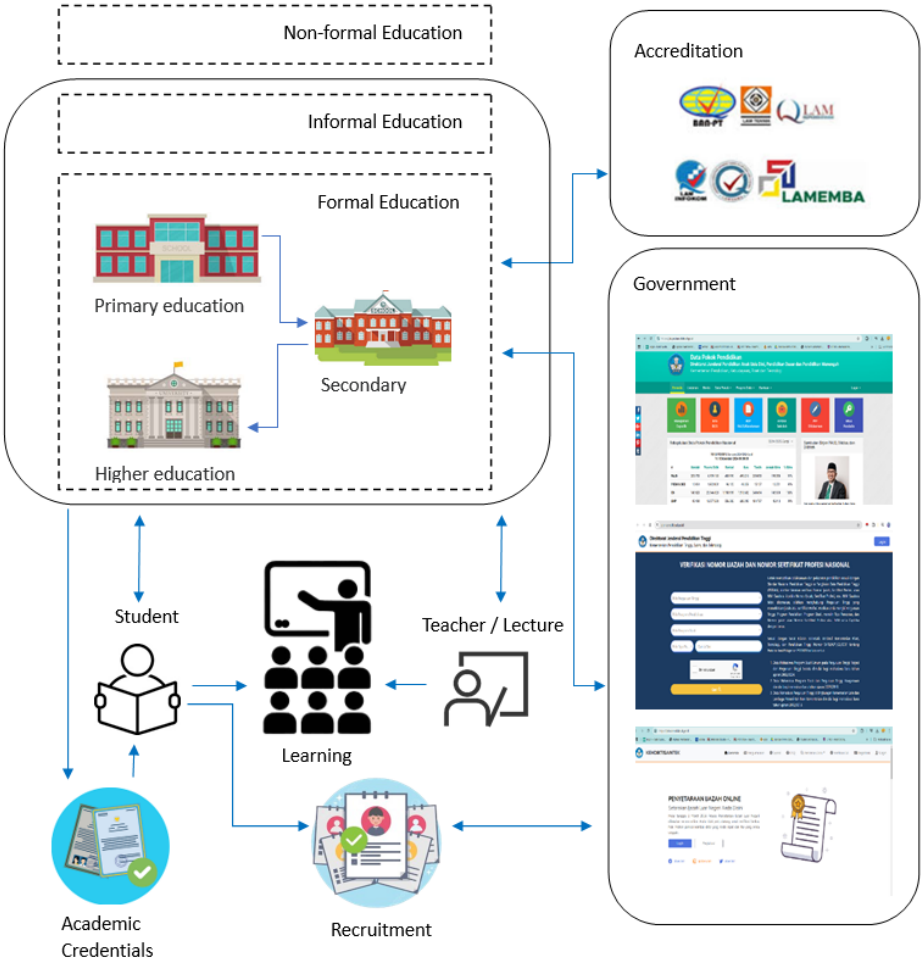

Figure 2. The educational process in Indonesia from elementary to higher education

System Information for education management in Indonesia uses digital technology, but is still centralized. The constraint is that the system relies on the Education data center server. Indonesian education data relies entirely on central servers (the Higher Education Database (PDDikti) and the Basic Education Database (DAPODIK)), which are managed exclusively by the government. The data verification process (such as academic credentials or student data) is carried out through a centralized mechanism. Centralized systems have problems such as Single Point of Failure, Vulnerability to Manipulation, and administrative inefficiency. This does not occur with a decentralized education system (Park, 2021).

Education paths, as defined by Article 1, number 7 of Law Number 20 of 2003 about the National Education System, are mechanisms by which students cultivate their potential within an educational process aligned with established educational objectives. The educational trajectory comprises:

a. Formal education is an organized and hierarchical educational system including elementary, secondary, and higher education.
b. Non-formal education is an educational pathway distinct from formal education, which may be executed in a systematic and hierarchical fashion.

c. Informal education encompasses familial and community-based educational pathways.

The level of education according to the provisions of Article 1 number 8 of Law Number 20 of 2003 concerning the National Education System:

a. Primary Education (9 years consisting of Elementary School (SD) for 6 years, Secondary School (SD) for 6 years, and Intermediate First (junior high school) for 3 years, which is education-based mandatory for all citizens)

b. Secondary Education comprises three years of Senior High School (SMA) or Vocational School (SMK).

c. Higher Education comprises diplomas, bachelor's, master's, and doctoral programs offered by universities, institutes, or polytechnics

The management of education is categorized into

a. Government.

    1) Central Government. Accountable for national policy, curriculum standards, accreditation, and educational funding.
    2) Local Government. Managing education at the provincial, district, and districts/cities, including developing schools, teacher recruitment, and distributing educational resources.

b. Private. Private Schools that follow a national or international curriculum but are managed by a private foundation or institution.

Every school and institution must be accredited to guarantee the caliber of instruction. The government has designated several accrediting organizations to oversee all of this. The issue is that not everyone is always aware of their school's or college's accreditation. The problem of the diploma's legitimacy is similar. Even though they use an information system, some of their data is inaccessible and must be obtained through specific parties. Students receive a diploma and a transcript with marks from the educational process that has been carried out. The transcript contains data on students' abilities in the form of values according to the curriculum implemented by schools or universities during the education process. Sometimes, Students do not know what curriculum they will be taking. The moment I pursue education, whether due to the desires and needs of students, the educational curriculum is also often not aligned with the needs of the world of work, so that graduates do not have the skills needed by the world of work. Many graduates work in fields unrelated to their background, beyond their education, which is a mismatch. One of the causes is that students often do not have adequate information about career opportunities and job market needs, so they choose majors that do not match their interests or potential. Likewise, the world of work does not know a school or any college with a curriculum that suits your company's needs. For the authenticity of the diploma, the government has made a system to check the certificate's authenticity. The data remains incomplete due to unregistered diplomas lacking information, and time is required to update the server with the most recent data. Counterfeit degrees and certifications represent a significant and growing concern. The same holds for fraudulent resumes and CVs, wherein job applicants incorporate inaccurate details regarding their qualifications, skills, and abilities (Kontzinos et al., 2024).

3.1.2. Examine the recent innovations in blockchain technology across the globe in the education sector.

Since the development of blockchain technology, which began with the launch of Bitcoin in 2009, many studies have been done to explore the potential of blockchain and its applications in various sectors, including education. Research early, focusing on blockchain applications for digitizing academic certificates in Brazil, highlighting the importance of transparency and security in academic management notes (Palma et al., 2019). As time passes, research develops with a broader focus, as seen in systematic reviews of initiatives and challenges in blockchain implementation in the education sector (Loukil et al., 2021; Rani et al., 2024). The development of significant others is seen in the development of micro-credentialing and digital badge systems, which aim to improve the confidence and skills of students (Alsobhi et al., 2023; Bathula et al., 2022). Blockchain is a technology based on a big distributed ledger (DLT) that stores and records data/information/transactions through a distributed and connected system using the concept of hashing (Alammary et al., 2019). The term Blockchain can be shared as block and chain. A block is a collection of linked data/information/transactions via a cryptographic hash to another block, automatically chronological in a virtual chain (Kontzinos et al., 2024). Blockchain can be categorized into three types: public, private, and consortium (Agarwal et al., 2021; Kontzinos et al., 2024). Blockchain categories are based on different parameters related to the education world, as seen in Table 2.

Table 2. Categorization of blockchain

Features / Properties	Public	Private	Consortium
Accessibility	Anyone	Single person/ central in charge	More than one person/in charge
Who can join?	Anyone	Authorized person	Authorized person
Permissioned	Transactions can be read and submitted by any nodes, but can only be validated by Authorized nodes.	Transactions can only be read, submitted, and validated by Authorized nodes.	Transactions can only be read, submitted, and validated by Authorized nodes.
Permissionless	Transactions can be read, submitted, and validated by any node.	Not applicable	Transactions can only be read and sent by any node that an authorized node has validated.
Consensus mechanism	PoS, PBFT, PoW, PoA	DpoS	PBFT, PoW, DPoS
Transaction speed	Slow	Fast	Faster than public
Structure	Decentralized	Centralized	Partially centralized
Central authority	None	Yes	Yes
Privacy	Through cryptography	Through restricted rights	Through restricted rights
Latency	Slow	Medium	Medium
No. of peers	High	Limited	Limited
Technology	Ethereum, R-CNN, ERC721 tokens, FenixEdu, QualiChain, IPFS, Bitcoin	Hyperledger fabric, IPFS, Hyperledger composer	Hyperledger Fabric, Hyperledger Sawtooth, ARK, Ethereum
Products / Solutions in the education sector	UNIC, KMI-OU-UK, MIT-ML, BlockCerts, RecordKeeper, Bcdiploma, NFTCert	-	SmartCert, VECefblock, UniverCert, INDISI
Applications	Certificate management, learning, Lifelong learning	Certificate management, examination review	Certificate management, learning, Fees, and credit transfer

Blockchain technology has surfaced as a solution, especially in traceability. Dependable traceability reduces the danger of data tampering, enhances transparency, preserves data integrity, and fosters decentralization (Amnur et al., 2025).

Consensus mechanisms (CMs). Consensus is how everybody in the blockchain network agrees on the present state of the network book, which is a huge database that is spread out over many computers. This process checks transactions and creates trust and dependability. Private blockchains like Hyperledger Fabric are widely used in institutional or consortium-led projects because they have controlled access, fast transaction speeds, and follow privacy rules. This makes them particularly good for academic networks with limited access and instructional databases run by the government. Consortium blockchains combine the best parts of both approaches, making it easier for different groups (such as colleges, accrediting organizations, and government agencies) to work together while still protecting privacy and keeping control over governance.

Students who finish the course are awarded a digital badge that symbolizes their abilities and learning outcomes in a given subject. Students who perform better than expected on assignments, tests, or courses might be awarded badges. Students and seekers can work on their wallets at the application level, where they can display their credentials. One such platform is QualiChain with six main layers in its technical architecture, which combines the intelligence and computation provided by data analysis and decision support with the security and transparency offered by blockchain to assist stakeholders in analyzing labor market and educational data, receive tailored advice, conduct analysis and support process decisions, and guarantee that credentials, skills, and education data can be stored safely and transparently validated (Kontzinos et al., 2024).

Table 3. Blockchain technology platforms in the world of education

No	Technology Blockchain	Understanding	Used By	Excess	Lack	Issue	Limitations	Citation
1	Bitcoin	First-generation blockchain for cryptocurrency	Bitcoin, Litecoin, Monero	Complete decentralization, High security, Transparency	High energy consumption, Low scalability (7 TPS), High transaction costs	Significant miner dominance doesn't support smart contracts	Not suitable for educational applications	(Delgado-von-Eitzen et al., 2021a, 2021b; Jirgensons & Kapenieks, 2018; Palma et al., 2019; Rani et al., 2024)
2	Ethereum	blockchain with smart contract	Ethereum, dApps, DeFi	Smart contract, Large ecosystem, Transition to PoS	Fluctuating gas fees, Limited scalability (15 TPS)	Smart vulnerability contract, Complexity	Still under development	(Alsobhi et al., 2023; Chawla et al., 2024; Delgado-von-Eitzen et al., 2021b; Loukil et al., 2021; Mainetti et al., 2022a; Manoj et al., 2021)
3	Hyperledger Fabric	Framework blockchain permissioned for enterprise	Educational institutions (UniChain), supply chain	High privacy, Good scalability, and Modular	Not fully decentralized, Complex setup	Less suitable for the public, needs special infrastructure	Limited to the consortium	(Alsobhi et al., 2023; Delgado-von-Eitzen et al., 2021b; Loukil et al., 2021; Rani et al., 2024)
4	Hyperledger Sawtooth	Blockchain with PoET for enterprise	Education (certificate management)	Energy saving, Fair node selection, Modular	Requires special hardware (SGX), Permissioned	Intel SGX Dependency	Limited adoption	(Alsobhi et al., 2023; Rani et al., 2024)
5	EduCTX	Blockchain specifically for educational credit transfer	Educational institutions	Special for education, Easy credit transfer	Limited network, depends on institutional participation	Limited interoperability	For academic credit only	(Alsobhi et al., 2023; Bhaskar et al., 2021; Delgado-von-Eitzen et al., 2021a, 2021b; Dwivedi & Vig, 2024; Nyazabe et al., 2023)

No	Technology Blockchain	Understanding	Used By	Excess	Lack	Issue	Limitations	Citation
6	Blockcerts	A Bitcoin-based solution for academic certificates	MIT Media Lab, a university	Simple, Integrated with Bitcoin	Scalability Bitcoin, Transaction fees	Dependence on Bitcoin	Limited functionality	(Alsobhi et al., 2023; Loukil et al., 2021)
7	NFTCert	blockchain for certificates	Education (anti-counterfeiting)	Unique and unforgeable, Clear proof of ownership	NFT minting costs, Price volatility	Technical understanding is required	Relatively new	(Rani et al., 2024)
8	VECefblock	blockchain solution for education certificates	Vietnamese educational institutions	Focus on certificate verification, Efficient for local	scalability, Complex architecture	Query a less efficient mechanism	Limited to Vietnam	(Rani et al., 2024)

Other studies show that blockchain could help solve the problem of supporting education in developing nations and make it easier to check and store academic credentials(Asamoah et al., 2023; Tara Chandra et al., 2024). The study has been increasingly varied and in-depth over time, notably between 2019 and 2022

Many studies have shown problems and chances for blockchain adoption. Despite significant advancements in blockchain applications within education, difficulties like as privacy, scalability, and technological acceptance continue to be the key focus (Palma et al., 2019; Rani et al., 2024). Future study should look into how to combine blockchain with other technologies and create a more complete plan on how to use it. This technology is relevant to diverse education.

Research is also beginning to concentrate on collaboration and social inclusion (Kwok & Treiblmaier, 2022). As we move into 2023 and beyond, research is looking increasingly at how blockchain may integrate with other technologies, like AI and the Internet of Things (IoT), to improve education. This illustrates that using these technologies together could make data secure and learning more fun (Agarwal et al., 2021; Shah et al., 2021). A major turning point in this development happened when people all across the world recognized that blockchain may improve system education and that more study needed to be done to solve problems that now exist. So, growth. This subject illustrates the evolution of technology and the necessity for individuals to adapt; continuing education has transformed in the digital era.

Recent research has focused on blockchain technology in education with particular attention to its impacts on transparency, security, and efficacy in the management of and processing of costs related to academic data in the privacy issue academic data management and processing costs (Alshareef, 2022). The use of blockchain technology in validating digital credentials and managing micro-credentials has emerged as one possible response to the challenges educational institutions face. This tech enabled 'collaboration' in educational institutions, governments, and the private sector is necessary to manage the balance of the technology; this also fulfills the legal framework of the data protection concerning the privacy and security of data. It is more effective to use blockchain technology to manage academic processes when compared to traditional systems that are inefficient and error-prone. This also supports the creation of a more effective and inclusive environment for learning.

3.1.3. Potential benefits, obstacles, and impact of implementing blockchain technology in the Indonesian education system

The analysis of the selected literature indicates that the use of blockchain in education isn't merely a tool for storing data. Instead, it represents a new paradigm for verifying credentials. While most studies focus on security and immutability, there are conflicting findings regarding the scalability of public and private blockchains. Some studies indicate that full transparency in public blockchains often conflicts with student data privacy regulations, while private blockchains offer greater control but with the inherent risk of centralization. Furthermore, this analysis identifies a significant research gap, with most studies remaining at the conceptual or limited simulation level. The lack of testing on real-world data loads and cross-institutional system integration are key unresolved barriers, necessitating a framework that addresses not only technical aspects but also organizational governance for widespread adoption of this technology.

3.1.3.1. Benefits

1) Improved Security and Verification. Blockchain significantly improves the security of educational data, reducing fraudulent academic credentials and other documents through decentralized verification and immutable records. It also simplifies competency validation and increases accountability for educational records. Blockchain inherently enhances security and efficiency in managing educational data, including student records, higher education data management, and secure data sharing for education with low error rates. It also ensures safe handling of academic data (Dash et al., 2022; Dwivedi & Vig, 2024; Loukil et al., 2021; Manoj et al., 2021; Nita & Mihailescu, 2024; Raimundo & Rosário, 2021; Rani et al., 2024; Samala et al., 2024; Tara Chandra et al., 2024).

2) Greater Accountability and Transparency. Blockchain improves accountability and transparency in educational records and systems. This technology simplifies educational administration and management by automating certificate issuance and credit transfer processes. (Alammary et al., 2019; Choi et al., 2019; Liu & Zhu, 2021; Loukil et al., 2021; Palma et al., 2019; Rani et al., 2024).

3) Enhanced Student Experience and Engagement. Blockchain supports competency-based education, increases student engagement through micro-credentials, smart badges, and gamification. Digital certification provides a better experience for students (Alshareef, 2022; Copenhaver & Pritchard, 2017; Mainetti et al., 2022a; Vordenberg et al., 2024).

4) Higher Quality Teacher Professional Development. Blockchain can improve the quality of teacher professional development through verified records and more secure resource sharing. (Meng, 2024).

5) Secure and Controlled Digital Identity Management. Users have more control over their digital identity data with enhanced security and privacy (Nita & Mihailescu, 2024).

6) Innovation in Learning and Resource Sharing. Blockchain facilitates more secure and efficient sharing of online teaching resources, increases the spread and speed of teaching/learning, and promotes social inclusion. It also supports more secure online testing and better data management (Chen et al., 2023; Hao et al., 2023; Kwok & Treiblmaier, 2022; Sun et al., 2018; Tsang et al., 2024; Zhao, 2024).

7) Prevention of Forgery and Improvement of Employment Opportunities. Adopting blockchain helps prevent forgery of academic documents and can improve job placement predictions (Kuleto et al., 2022a; Nyazabe et al., 2023; Shah et al., 2021).

8) Interoperability and Standardization. Blockchain improves interoperability and standardization of credentials in education, as well as facilitating the recognition of qualifications across institutions. (Bhaskar et al., 2021; Ocheja et al., 2022).

3.1.3.2. Obstacles

1) Lack of Research. Many existing studies are descriptive with small sample sizes and lack extensive research, especially in areas such as the design and implementation of micro-credentials (MCs) and digital badges (DBs) in specific programs. Further validation in real-world scenarios is needed to confirm the potential of blockchain use cases in education (Manoj et al., 2021; Tara Chandra et al., 2024; Yfantis & Ntalianis, 2022).

2) Scalability Issues. Potential scalability issues and reliance on a particular platform or model (e.g., Ethereum or deep learning models) are limitations. The sheer size of education data has also not been widely considered (Bathula et al., 2022; Bhaskar et al., 2021; Chen et al., 2023; Choi et al., 2019; Copenhaver & Pritchard, 2017; Kontzinos et al., 2024; Loukil et al., 2021; Samala et al., 2024; Shah et al., 2021; Son-Turan, 2022; Yfantis & Ntalianis, 2022; Zhao, 2024).

3) Constraints of Study Scope and Generalizability. Many studies are limited to one or two institutions, a particular geographic region (e.g., Delhi-NCR, Saudi Arabia), or a type of institution (e.g., private universities), making it difficult to generalize the findings to other contexts (Alshareef, 2022; Alsobhi et al., 2023; Bhaskar et al., 2021; Copenhaver & Pritchard, 2017; Dwivedi & Vig, 2024; Jirgensons & Kapenieks, 2018; Kwok & Treiblmaier, 2022; Lizcano et al., 2019; Meng, 2024; Samala et al., 2024; Shah et al., 2021; Tara Chandra et al., 2024; Tsang et al., 2024; Vordenberg et al., 2024).

4) Adoption Challenges. Slow adoption in education, lack of incentives, and the need for a strong legal framework to protect users are significant barriers. The complexity of the technology, the need for user training, and

information security issues are also concerns (Asamoah et al., 2023; Bhaskar et al., 2021; Loukil et al., 2021; Manoj et al., 2021; Nita & Mihailescu, 2024; Park, 2021; Rani et al., 2024).

5) Limited Focus. Most studies focus on certificates, with limited exploration of in-depth academic records and interoperability issues. Some studies may also ignore other core elements of education by focusing solely on teaching/learning. (Dash et al., 2022; Dwivedi & Vig, 2024; Kuleto et al., 2022a; Ocheja et al., 2022; Raimundo & Rosário, 2021; Son-Turan, 2022).

6) Legal and Cost Issues. Legal issues associated with blockchain. The immutable nature of records (difficult to change if an error occurs) and high implementation costs may hinder wider adoption. (Agarwal et al., 2021; Loukil et al., 2021; Nita & Mihailescu, 2024).

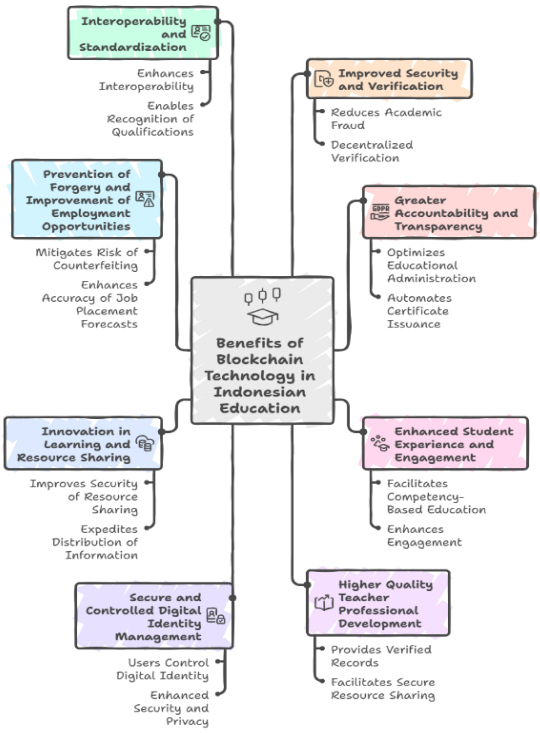

Figure 3. Benefits of BT in Indonesian Education

3.1.3.3. Impact

1) Credential Verification and Security. The implementation of this technology significantly improves the security, efficiency of verifying and storing academic documents (including diplomas, transcripts, and certificates). It also addresses document forgery and enhances credibility (Alammary et al., 2019; Bhaskar et al., 2021; Ocheja et al., 2022; Rani et al., 2024; Samala et al., 2024; Shah et al., 2021; Tan et al., 2023; Tara Chandra et al., 2024).

2) Micro Credentials, Digital Badges. Facilitate developers as well as management of micro-credentials and digital badges. Enable more detailed skill recognition and increase student engagement through gamification. (Alsobhi et al., 2023; Choi et al., 2019; Copenhaver & Pritchard, 2017; Kontzinos et al., 2024; LaMagna, 2017; Vordenberg et al., 2024).

3) Teacher Professional Development, Assessment. It can have a positive impact on professional development as well as teacher assessment through verified and transparent records. (Choi et al., 2019; Jirgensons & Kapenieks, 2018; Meng, 2024)

4) Digital Identity Management and User Control. It can empower users with greater control over their digital identity in educational contexts, while enhancing security and privacy.(Bhaskar et al., 2021; Chen et al., 2023; Jirgensons

& Kapenieks, 2018; Nita & Mihailescu, 2024; Palma et al., 2019; Park, 2021; Raimundo & Rosário, 2021; Zhao, 2024).

5) Transformation of the Education System. This application has the potential to transform the education system, including the public sector, by increasing transparency, security, and efficiency. Integration with IoT and AI can also accelerate this transformation. (Agarwal et al., 2021; Bhatia & Bhasin, 2023; Pongnumkul et al., 2021).

6) Student Experience and Sustainability. Blockchain-based digital certification improves the student experience. This technology also supports a more sustainable education system and the adaptation of higher education business models. (Alshareef, 2022; Kuleto et al., 2022b; Mainetti et al., 2022b; Shah et al., 2021).

7) Credit Transfer and Administration. Blockchain implementation can simplify and secure the credit transfer system between educational institutions and improve educational administration and management (Manoj et al., 2021; Park, 2021)

8) Digital Learning Assessment and Management. Blockchain enhances the assessment and management of digital learning credentials through a digital badge system for performance assessment. (Choi et al., 2019; Jirgensons & Kapenieks, 2018; Meng, 2024)

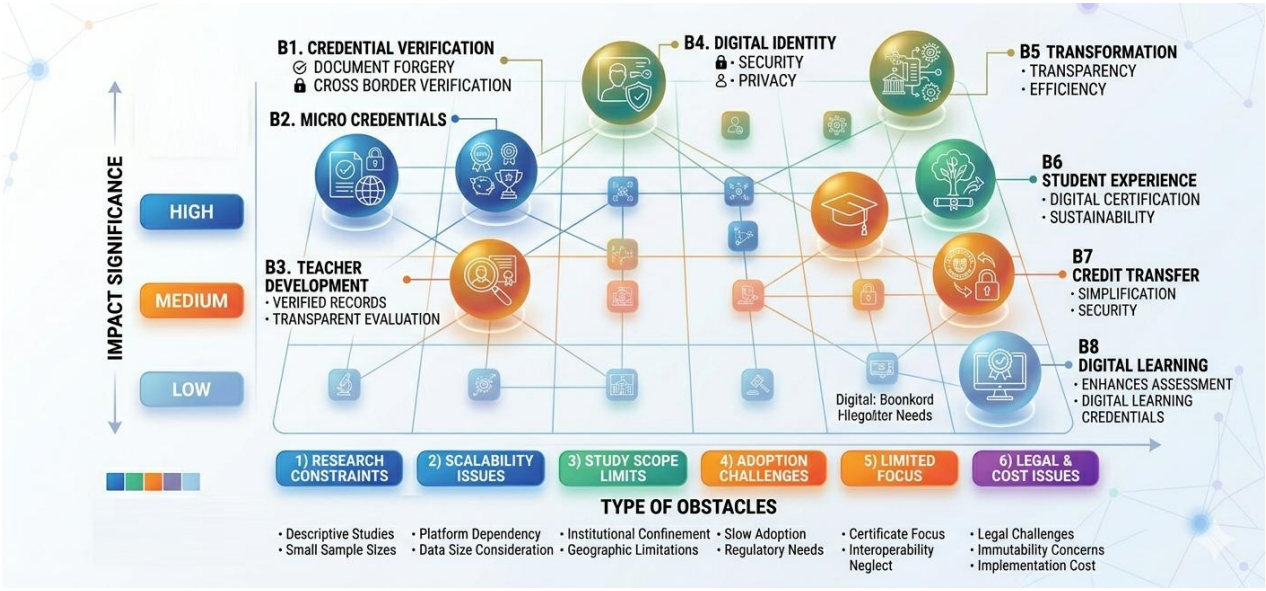

Figure 4. The Relationship between the Obstacles Matrix and the Impact of Blockchain Implementation

3.2. Discussion

The present systematic review illustrates that the education system in Indonesia is facing numerous obstacles, especially with regard to the forgery of academic credentials, as well as the integrity of data. This is similarly the case in a global context. These findings are consistent with previous research confirming that conventional education systems are vulnerable to data manipulation, slow bureaucracy, and limitations in cross-institutional and cross-country verification of academic credentials (Alammary et al., 2019; Bhaskar et al., 2021; Rani et al., 2024). This study focuses on Indonesia's complex national education management system, which includes central government, local governments, and private institutions, making the creation of an integrated and trustworthy system crucial. This system currently still has a centralized verification mechanism, making it vulnerable to delays and security vulnerabilities

Blockchain technology offers solutions to the challenges facing the education system in Indonesia. PDDikti and DAPODIK will continue to function as primary data storage (off-chain storage), while the blockchain acts as an on-chain verification layer, storing digital fingerprints (hashes) of the documents. This model allows for a period of secure coexistence, where data integrity is guaranteed by the blockchain without requiring a complete overhaul of the current central infrastructure.

This study highlights how the immutable nature of blockchain ledgers can create a missing "trust model" in the education ecosystem. Given the extensive research on certificate verification, the adoption of a decentralized verification system in Indonesia could address the problem of forged certificates through immediate and irreversible verification.

To address the blockchain immutability dilemma, where administrative errors are difficult to reverse, this framework introduces a subsection on 'Data Correction Protocols'. The proposed solution is the implementation of 'Correction Transaction' logic, whereby any incorrect input is not removed from the data chain but instead issues a new transaction referencing the old block as obsolete. This approach ensures that the integrity of the audit trail is transparently maintained while providing the administrative flexibility necessary to correct data without disrupting the existing decentralized structure.

Although Centralized Education Information Systems (CEIS) that are housed within government servers are beneficial for the formulation of educational policies, they tend to encumber data accessibility. It can be said, therefore, that the application of blockchain does not fully remove the government's 'hands-off' approach. The Ministry of Education (Kemendikbudristek) is designated as the root node manager, which regulates access policies. Meanwhile, educational institutions (universities and schools) act as issuing nodes with exclusive rights to issue academic credentials, creating a distributed yet controlled governance ecosystem. Instead, it places the system within a 'participatory' blockchain framework where there is greater collaboration and role differentiation among the various actors within the system: the universities, the accreditation body, and the government, with respect to the verification of the transactions. It can be said that, with blockchain, students are given the concept of 'independent identity' for the first time.

This study differs from other studies that focus on the use of blockchain technology in one organization in one country. This study shows that a blockchain approach can be a potential solution for every educational sector in Indonesia, be it formal, non-formal, or informal. This study is useful for Indonesian policymakers and educational administrators. The main goal of utilizing blockchain technology is to provide better security and trust in academic diplomas through a record-keeping system that cannot be altered, coupled with a verification system that is not restricted to a single institution. This would help to eliminate the enduring problem of diploma and certificate fraud. First, blockchain is crucial for tracking educational data flows and integrating the currently fragmented national education system. Second, blockchain can enhance educational management by automating tedious and labor-intensive processes such as certificate issuance, credit transfers, and the verification of academic information. Third, a blockchain system will provide students and teachers with more control over their digital identities and academic records. Fourth, the use of blockchain can help create a better balance between education and the needs of the workforce. Micro-certificates and digital badges based on blockchain technology will enable the education sector to track and verify graduates' personalized competencies in a clear and transparent manner. This is consistent with previous research that highlights the potential of blockchain technology in enhancing graduates' employability and better aligning educational outcomes with the needs of the labor market (Kuleto et al., 2022b; Shah et al., 2021). Hence, blockchain technology can be viewed as a potential strategic facilitator of the connectivity between educational institutions and the labor market in Indonesia. Additionally, this study reveals the potential of blockchain as not only a technology tool but also as a means to establish a more transparent and accountable framework for the governance of educational data that is missing in the current system.

This study contributes to the body of literature that applies a more sophisticated approach in stating that blockchain technology can be viewed as a national infrastructure for trust and traceability, beyond the limitations of being a tool for the verification of certificates. The innovation of this study is in providing a more comprehensive and systematic account of the interplay of challenges and prospects of blockchain technology within the educational ecosystem in Indonesia, which has garnered very little scholarly attention. By juxtaposing the globally established trends in blockchain technology with the unique legislative and institutional context of Indonesia, this study provides a valuable contribution toward educational traceability, operational alignment, and policy alignment that blockchain technology has the potential to offer.

In the context of Indonesia's education system, these global findings present both unique opportunities and challenges. The decentralized architecture of blockchain technology could serve as a practical solution to problems related to fake diplomas and the fragmentation of data between PDDikti and local educational institutions. However, its implementation must take into account the uneven development of Internet infrastructure and the legal framework surrounding digital signatures based on smart contracts. This study has its limitations, as it relies solely on data from Scopus. This may lead to biases in the analysis of global publications, while ignoring studies published in national journals. Additionally, there is a lack of thorough quality assessment of each piece of literature included in the study.

Therefore, future research should focus on developing prototypes that are compatible with Indonesia's government's information technology infrastructure, as well as exploring public policies that can support this digital transformation.

3.3. Limitations and directions for future research

3.3.1. Limitations

Even though this study offers a preliminary understanding of the possibilities of blockchain technology in Indonesia via systematic literature review, it has some drawbacks, such as:

a. The majority of the reviewed literature considers blockchain technology as a single, homogeneous layer. Some of these studies fail to grasp the integration of blockchain with traditional systems, such as PDDikti and DAPODIK, in Indonesian education.
b. There is a literature gap as the existing literature is a theoretical framework based on secondary Scopus data in addition to the existing literature, and the study at the national level on the blockchain is almost non-existent in a high volume transactional (e.g. thousands of graduation verification at universities).
c. Indonesia is an archipelagic country with uneven internet access.

3.3.2. Directions for future research

Future research should focus on creating a robust technical framework to alleviate the previously mentioned limitations.

a. Future research should create and use a prototype reference architecture that can effectively combine Indonesia's complex education (in the business world) with smart contract logic. Also, this design is important for keeping parts of the system separate so that heavy loads on one service don't make the whole network unavailable.
b. Due to the large amount of education data in Indonesia, a single blockchain network could get too busy. Future research should investigate the operational dynamics of various entities on their sidechains or subnets, connecting foundational evidence to the primary chain. This method provides the perfect mix between data sovereignty, privacy, and system scalability as compared to standard single-chain federations.

It is necessary to conduct research to create standard communication protocols that will make it easier for the Ministry of Education, universities, and businesses to share information.

4. Conclusion

This study identifies the challenges Indonesian education system faces and analyzes the potential of blockchain system within the said challenges. The Indonesian education system faces challenges such as fake diplomas, unequal distribution of resources, poor management, falsified documents, lack of transparency, poor data management, fragmentation and interoperability. Indonesian has an educational information system but it's a risk the system is centralized to be abused. This study follows the PRISMA guidelines and analyzes extensive literature. The author finds that the challenges can be overcome using the enduring potential of blockchain to bring sustainable transparent and accountable stored value systems.

Blockchain can be utilized to improve data safety, identity management, and education management. The introduction of blockchain in Indonesia is expected to improve data safety, accountability, user experience of the students and professional development of teacher. Also, the combination of blockchain features like decentralized identity and access management will reduce fraud, increase transaction speed and improve collaboration between educational institutions.

The report discusses possible challenges that may arise during the execution of the project that may include lack of appropriate technology, rule ignorance, insufficient scalability, cross disciplinary collaboration with experts, etc. When it comes to the implementation of blockchain technology, a cohesive structure, well defined regulations, partnerships between the private sector, public sector, and educational institutions are required.

Even with that said, the potential impact is estimated to be considerable. Blockchain technology has the potential to transform educational processes by providing seamless validation of micro-credentials, more effective school and education system management, and increased system openness and sustainability. According to the National Cybersecurity Strategy, blockchain helps to protect the educational data of Indonesians and, by extension, the education system, due to the security features of blockchain technology including zero trust and audit trails. For Indonesia to reap

the benefits of blockchain technology, more inclusive cross sector pilot projects and policies are needed. This will improve the systems of education in Indonesia to be more open, secure, and resilient.

To fully realize the benefits, and make Indonesia's education system more open, flexible, traceable, secure and future-ready, there is a need for pilot projects and policies that can reach a diverse and broad population.

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