BLOCKCHAIN FOR VERIFIABLE ACADEMIC CREDENTIALS IN THE EDUCATION SECTOR

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Use Case Report

submitted by

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Kanuru, Vijayawada-520 007

2024-25

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CERTIFICATE

This is to certify that the Use Case report entitled **"BLOCKCHAIN FOR VERIFIABLE ACADEMIC CREDENTIALS IN THE EDUCATION SECTOR"** that is being submitted by **N. Venkatesh (22501A05C6),** as part of Assignment-1 and Assignment-2 for the **Blockchain Technology**(**20CS4601C)** course in **3-2** during the academic year **2024-25**.

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1.INTRODUCTION

Academic credentials play a vital role in verifying an individual's educational qualifications, which are essential for accessing higher education, securing employment, and obtaining professional certifications. However, traditional credential management systems face multiple challenges, including document forgery, loss of records, manual verification delays, and administrative inefficiencies. These challenges lead to a lack of trust in academic qualifications and create significant burdens for educational institutions, employers, and credentialing bodies [1].

The current verification process is often slow and costly, requiring third-party verification services that rely on centralized databases. Such databases are vulnerable to cyberattacks, unauthorized modifications, and data breaches. Fraudulent degrees and certificates have become a major concern, with employers struggling to authenticate academic credentials effectively. A more secure, efficient, and transparent system is necessary to address these issues [2].

Blockchain technology presents a revolutionary approach to academic credentialing by providing a decentralized, tamper-proof, and easily verifiable system. Unlike conventional methods that depend on central authorities, blockchain records academic credentials on a distributed ledger that ensures immutability and security. Once a credential is issued on the blockchain, it cannot be altered or deleted, eliminating risks of forgery or unauthorized modifications. Each academic certificate is cryptographically signed, allowing instant and trustless verification without intermediaries [3].

Security and privacy are crucial aspects of digital credential management. Blockchain technology utilizes cryptographic hashing, decentralized validation, and consensus mechanisms to ensure data integrity and authenticity. Additionally, smart contracts can automate credential issuance, verification, and authentication processes, reducing the need for manual intervention and minimizing human errors. These features not only enhance security but also streamline administrative processes, saving time and operational costs for institutions and employers [4].

Accessibility is another significant advantage of blockchain-based credentialing. Traditional systems often require physical documents, which can be lost, damaged, or difficult to verify across borders. Blockchain enables students and professionals to store and share their verified credentials securely using digital wallets, making the verification process faster and more cost-effective for universities, employers, and licensing bodies. This also promotes inclusivity by allowing individuals from remote locations or disadvantaged backgrounds to access and prove their qualifications without bureaucratic hurdles [5].

By integrating blockchain technology into academic credentialing, educational institutions can enhance transparency, prevent degree fraud, and increase trust in qualifications. Governments and private organizations worldwide are exploring blockchain-based solutions to modernize education and employment systems. As the global demand for secure and verifiable digital credentials continues to rise, blockchain offers an innovative and scalable solution that ensures integrity, efficiency, and reliability in academic record management [6].

2.BACKGROUND

The need for a secure, verifiable, and efficient academic credentialing system has become increasingly important in the modern education sector. Traditional methods of credential verification rely on centralized authorities such as universities, government agencies, and third-party verification services. However, these systems face significant limitations, including the risk of fraud, inefficiencies in manual verification, and a lack of global accessibility [1].

One of the primary challenges with traditional credentialing is document forgery. Fake degrees, manipulated transcripts, and diploma mills have become widespread, making it difficult for employers and institutions to distinguish between genuine and fraudulent qualifications. Many cases have surfaced where individuals have secured jobs or admissions using forged certificates, undermining the credibility of academic institutions and harming the job market's integrity [2]. Since traditional databases store academic records in centralized repositories, they are vulnerable to cyberattacks, unauthorized modifications, and data breaches. If an institution's database is compromised, records can be altered or lost, raising concerns about data security and long-term credential verification [3].

Another major issue is the inefficiency of manual verification processes. Currently, employers, universities, and government agencies must reach out to issuing institutions or third-party verifiers to confirm the authenticity of an academic credential. This process is often time-consuming and expensive, taking weeks or even months to complete, particularly in cases involving international verification. Additionally, if an institution closes down or loses records due to unforeseen circumstances, verifying past academic credentials becomes nearly impossible, leaving graduates without proof of their qualifications [4].

The absence of a standardized framework for credential verification further complicates the process. Different countries, universities, and organizations use varied methods to store and authenticate academic records, leading to inconsistencies. Employers and academic institutions must navigate multiple verification systems, increasing administrative workload and costs. Moreover, students and professionals often face challenges when applying for jobs or higher studies abroad due to differences in credential recognition and validation processes [5].

Blockchain technology has emerged as a revolutionary solution to these challenges. Unlike centralized databases, blockchain operates on a decentralized network, ensuring that once a credential is recorded, it cannot be altered or falsified. This immutability enhances trust and transparency in the credentialing process. Additionally, blockchain eliminates the need for third-party verification, allowing employers, universities, and certification agencies to verify credentials instantly without relying on intermediaries [6].

Several universities, government bodies, and organizations have already begun adopting blockchain-based credentialing systems. Institutions such as MIT, Harvard, and the University of Melbourne have issued blockchain-based digital diplomas and certificates, allowing students to share their verified credentials securely. Governments in countries like Malta and Estonia have also explored blockchain for educational record-keeping, demonstrating its potential in academic credentialing. As regulatory frameworks evolve and technological advancements continue, the adoption of blockchain for academic credentials is expected to expand further, providing a more efficient and secure alternative to traditional verification methods [7].

By leveraging blockchain technology, the education sector can transition from outdated, paper-based credentialing systems to a digital, transparent, and universally accessible model. This transition will not only improve trust in academic qualifications but also streamline verification processes, reduce fraud, and increase accessibility for students and professionals worldwide [8].

3.BLOCKCHAIN BASICS

Blockchain is a decentralized, distributed ledger technology that enables secure and tamper-proof record-keeping. It operates without a central authority, ensuring transparency, immutability, and security in data storage and transactions. In the context of academic credentialing, blockchain provides an efficient way to issue, store, and verify credentials, eliminating the risks associated with traditional centralized databases [1].

3.1 Key Features of Blockchain in Academic Credentialing

Decentralization

Unlike conventional credentialing systems controlled by a single authority, blockchain distributes control across multiple nodes, preventing fraud, data loss, and unauthorized alterations. Every participant in the network maintains a copy of the credential records, ensuring that no single entity can manipulate or delete data [2].

Immutability and Security

Once an academic credential is recorded on the blockchain, it cannot be altered or deleted. Blockchain uses cryptographic hashing to secure records, making it nearly impossible for malicious actors to modify stored credentials. This ensures that academic qualifications remain verifiable and tamper-proof [3].

Transparency and Trust

Blockchain allows institutions, employers, and students to verify credentials in real-time. Every recorded transaction on the blockchain is time-stamped and accessible for verification, ensuring trust in academic records without relying on intermediaries [4].

Smart Contracts for Automation

Smart contracts are self-executing programs stored on the blockchain that automate credential issuance and verification. When a student completes a degree, a smart contract can instantly issue a digital certificate and register it on the blockchain. This reduces administrative work and human errors in the verification process [5].

Cryptographic Security

Academic credentials stored on the blockchain are protected using cryptographic techniques such as hashing and digital signatures. Each credential is assigned a unique cryptographic hash, preventing unauthorized modifications and ensuring secure authentication [6].

3.2 Components of a Blockchain-Based Credentialing System

Distributed Ledger

A blockchain ledger records all issued credentials, ensuring that data remains secure, verifiable, and tamper-proof. This ledger is accessible to authorized users for instant verification [7].

Consensus Mechanisms

Blockchain networks use consensus mechanisms to validate and add transactions. Common methods include:

- **Proof of Work (PoW):** Requires computational effort to validate transactions, ensuring security but consuming more energy.
- **Proof of Stake (PoS):** Assigns validation power based on ownership, offering energy-efficient and faster processing.
- **Permissioned Blockchain:** A private blockchain where only verified participants (e.g., universities, employers) can validate credentials, ensuring controlled access [8].

Public and Private Keys for Authentication

Blockchain credentialing uses public and private key cryptography. Institutions use private keys to sign issued credentials, while students and employers use public keys for verification. This ensures that only authorized parties can access academic records securely [9].

Interoperability and Global Access

Blockchain-based credentials are easily shareable across institutions and employers worldwide. A universal standard for digital credentials would allow seamless integration between different educational systems, improving global mobility for students and professionals [1].

3.3 Advantages of Blockchain-Based Academic Credentialing

Fraud Prevention

Since blockchain records cannot be altered, fraudulent certificates and degree forgery become impossible. Institutions and employers can instantly verify credentials, reducing the risk of hiring unqualified candidates [2].

Efficiency and Cost Reduction

Traditional verification processes involve intermediaries, manual checks, and long wait times. Blockchain automates credential issuance and verification, reducing administrative costs and processing time [3].

Global Accessibility and Remote Verification

Students and professionals can access and share their credentials digitally from anywhere in the world. Employers and institutions can verify academic qualifications instantly, eliminating the need for physical documents [4].

Long-Term Data Preservation

Unlike paper-based certificates, which can be lost or damaged, blockchain ensures lifelong storage of academic credentials. Even if an educational institution ceases operations, credentials stored on the blockchain remain accessible and verifiable [5].

As blockchain adoption in education grows, universities and employers will benefit from a streamlined, fraud-proof, and globally accessible credentialing system. By leveraging blockchain's security, transparency, and automation capabilities, academic institutions can modernize credential issuance and verification, ensuring a future-proof academic record management system [6].

4.USE CASE OVERVIEW

Academic credential verification is a critical process that ensures the authenticity of an individual's educational qualifications. However, traditional verification methods rely on centralized authorities, manual verification processes, and paper-based records, leading to inefficiencies, fraud risks, and delays. Blockchain technology offers a transformative solution by enabling decentralized, transparent, and tamper-proof credentialing systems [1].

Blockchain-Based Credentialing Model

The following diagram illustrates the blockchain-based credentialing process, demonstrating how academic institutions issue credentials, students store them in digital wallets, and third-party verifiers authenticate them using blockchain technology.

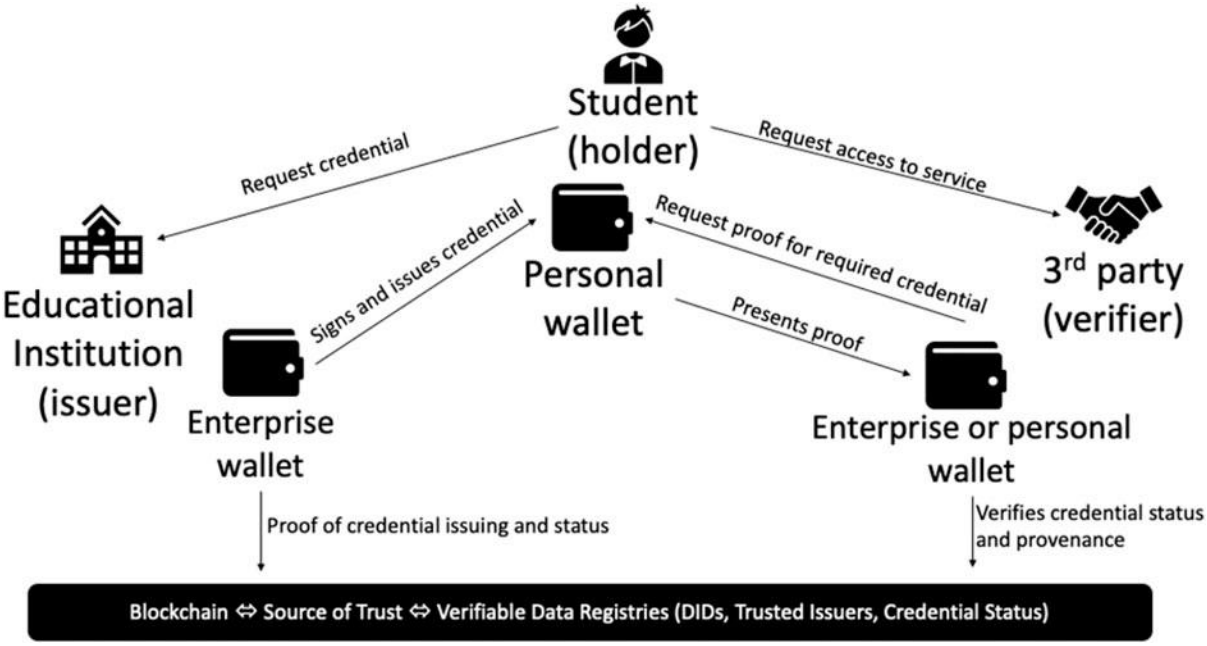

Fig 4.1: Blockchain-Based Secure and Transparent Academic Credential System

4.1 Objectives of Blockchain-Based Credentialing

The primary objectives of using blockchain for academic credential verification include:

- **Enhancing Transparency:** Blockchain provides an immutable and publicly verifiable ledger of academic credentials, ensuring trust in the verification process [2].
- **Preventing Credential Fraud:** Digital certificates recorded on the blockchain cannot be forged, manipulated, or altered, eliminating fraudulent degree claims [3].
- **Improving Efficiency:** By eliminating intermediaries, blockchain reduces the time and cost associated with manual verification, making the process faster and more reliable [4].
- **Ensuring Global Accessibility:** Students and professionals can securely store and share their credentials digitally, facilitating seamless cross-border verification for employment and further education [5].
- **Automating Verification Processes:** Smart contracts can automate credential issuance, revocation, and verification, reducing administrative overhead and human errors [6].

4.2 Scope of Blockchain in Academic Credentialing

Blockchain-based academic credentials can be applied in various domains, including:

- **University Degrees and Diplomas:** Universities can issue digital degrees directly on the blockchain, ensuring instant and tamper-proof verification.
- **Professional Certifications:** Certification bodies can securely store and verify professional credentials, reducing the risk of fake certificates in industries such as IT, healthcare, and finance [7].
- **Transcript Verification:** Students can store and share verified academic records with employers and educational institutions without relying on third-party verification services.
- **Scholarship and Financial Aid Records:** Blockchain can securely track eligibility and disbursement of scholarships, grants, and financial aid [8].
- **Skill-Based and Micro-Credentials:** Online learning platforms and training institutes can issue blockchain-based credentials for skill development programs, making them easily verifiable.

4.3 Architecture of a Blockchain-Based Credentialing System

A blockchain-based academic credentialing system consists of multiple components working together to ensure security, transparency, and efficiency:

1. Blockchain Layer

- **Decentralized Ledger:** Stores all academic credentials securely and ensures that records are immutable.
- **Consensus Mechanism:** Uses Proof of Stake (PoS) or permissioned blockchain models to validate and store credentials efficiently [9].

2. Identity Verification Layer

- **Student Authentication:** Uses government-issued IDs, biometric verification, or digital signatures to verify students before issuing credentials.
- **Zero-Knowledge Proofs (ZKP):** Ensures that credentials are verifiable without exposing sensitive personal data.

3. Credential Issuance and Smart Contract Layer

- **Smart Contracts:** Automate the issuance, validation, and revocation of academic credentials.
- **Encrypted Digital Certificates:** Credentials are stored as cryptographically signed tokens, ensuring security and authenticity.

4. User Interface Layer

- **Web and Mobile Applications:** Provides a user-friendly platform for students, employers, and institutions to manage credentials.
- **QR Code-Based Verification:** Employers and institutions can verify credentials instantly by scanning a QR code linked to the blockchain record.

4.4 Benefits of a Blockchain-Based Credentialing System

1. **Eliminates Credential Fraud:** Immutable records ensure that academic qualifications cannot be tampered with or forged [1].
2. **Reduces Verification Time and Cost:** Instant verification eliminates the need for lengthy and expensive manual verification processes [2].
3. **Enhances Data Security and Privacy:** Cryptographic security measures prevent unauthorized access to academic records [3].
4. **Enables Global Credential Mobility:** Students can seamlessly share their credentials across institutions and employers worldwide [4].

5. **Facilitates Lifelong Learning Records:** Blockchain enables individuals to maintain a permanent, verifiable record of their educational achievements and skills [5].

As more educational institutions and employers recognize the advantages of blockchain-based credentialing, its adoption is expected to increase, providing a future-proof solution for academic verification and digital identity management.

5.IMPLEMENTATION

Blockchain-based academic credentialing involves multiple components, including credential issuance, storage, verification, and access management. The implementation leverages **smart contracts**, **cryptographic security**, and **decentralized identity (DID) standards**.

5.1 System Architecture

A blockchain-based academic credentialing system consists of:

- **Issuer (Educational Institution):** Issues digital credentials using smart contracts.
- **Holder (Student):** Stores and manages credentials in a digital wallet.
- **Verifier (Employer/Institution):** Requests proof of credentials from students.
- **Blockchain Network:** Stores immutable credentials and enables decentralized verification.
- **Smart Contracts:** Automate credential issuance, validation, and revocation.

5.2 Smart Contract for Credential Issuance

A **Solidity-based smart contract** ensures secure and tamper-proof issuance and verification.

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract AcademicCredential {
    struct Credential {
        string studentName;
        string degree;
        string institution;
        string issueDate;
        bool isValid;
    }

    mapping(bytes32 => Credential) public credentials;
    address public issuer;

    modifier onlyIssuer() {
        require(msg.sender == issuer, "Not authorized");
        _;
    }

    constructor() {
        issuer = msg.sender;
    }

    function issueCredential(
        string memory _studentName,
        string memory _degree,
        string memory _institution,
        string memory _issueDate
    ) public onlyIssuer returns (bytes32) {
        bytes32 credentialHash = keccak256(abi.encodePacked(_studentName, _degree, _institution, _issueDate));
        credentials[credentialHash] = Credential(_studentName, _degree, _institution, _issueDate, true);
        return credentialHash;
    }

    function verifyCredential(bytes32 credentialHash) public view returns (bool) {
        return credentials[credentialHash].isValid;
    }
```

```
    function revokeCredential(bytes32 credentialHash) public onlyIssuer {
        credentials[credentialHash].isValid = false;
    }
}
```

5.3 Decentralized Identity (DID) and Verification

- **Self-Sovereign Identity (SSI):** Students control their credentials without intermediaries.
- **Zero-Knowledge Proofs (ZKP):** Allows verification without revealing sensitive data.

5.4 User Interface and QR Code-Based Verification

A **React.js frontend** can integrate Web3.js to interact with the smart contract and allow students/employers to verify credentials.

React.js Web3 Integration

```
import { useState } from 'react';
import Web3 from 'web3';
import credentialABI from './credentialABI.json';

const web3 = new Web3(Web3.givenProvider);
const contractAddress = "0xYourContractAddress";
const contract = new web3.eth.Contract(credentialABI, contractAddress);

function VerifyCredential() {
    const [credentialHash, setCredentialHash] = useState('');
    const [isValid, setIsValid] = useState(null);

    const checkCredential = async () => {
        const result = await contract.methods.verifyCredential(credentialHash).call();
        setIsValid(result);
    };

    return (
        <div>
            <input type="text" placeholder="Enter Credential Hash" onChange={e =>
setCredentialHash(e.target.value)} />
            <button onClick={checkCredential}>Verify</button>
            {isValid !== null && <p>Credential is {isValid ? "Valid" : "Invalid"}</p>}
        </div>
    );
}

export default VerifyCredential;
```

5.5 Benefits of the Implementation

1. **Security & Integrity:** Credentials are immutable and tamper-proof.
2. **Efficiency:** Instant verification without intermediaries.
3. **Privacy:** Users control access to their credentials.
4. **Scalability:** Supports multiple institutions and credential types.
5. **Global Recognition:** Ensures seamless cross-border verification.

6.ADVANTAGES

6.1 Security & Integrity

- Blockchain ensures **immutable** and **tamper-proof** credential storage, preventing unauthorized modifications and data loss.
- Cryptographic hashing and decentralized storage eliminate the risk of single-point failures, enhancing the security of academic records.
- Digital signatures validate the authenticity of credentials, ensuring they remain verifiable throughout an individual's lifetime.

6.2 Decentralization & Trust

- Eliminates reliance on a central authority for credential verification, reducing bureaucratic inefficiencies.
- A trustless system where verification is **automated** via smart contracts, removing the need for third-party validation.
- Ensures that no single entity can manipulate or revoke credentials unfairly, maintaining impartiality in academic record-keeping.

6.3 Instant & Cost-Effective Verification

- Employers and institutions can verify credentials **instantly** by accessing the blockchain, without requiring lengthy manual processes.
- Reduces administrative workload and associated costs related to document processing, storage, and verification requests.
- Streamlines recruitment and admissions by providing real-time access to verifiable academic records.

6.4 Privacy & User Control

- Students have complete control over their credentials through **Self-Sovereign Identity (SSI)**, allowing them to manage their academic records independently.
- Enables selective disclosure using **Zero-Knowledge Proofs (ZKP)**, allowing users to prove possession of credentials without revealing unnecessary personal information.
- Prevents unauthorized data access, ensuring compliance with data privacy regulations such as GDPR and CCPA.

6.5 Scalability & Interoperability

- Supports multiple institutions, credentials, and verification standards, making it adaptable across different education systems.
- Compatible with global verification systems, ensuring **cross-border recognition** and simplifying international academic mobility.
- Can be integrated with existing educational databases and credentialing platforms, enhancing flexibility and usability.

6.6 Fraud Prevention & Transparency

- The public ledger provides transparency while maintaining privacy, allowing institutions and employers to validate credentials efficiently.
- Helps prevent credential fraud by ensuring that every issued certificate is cryptographically secured and recorded on an immutable ledger.
- Detects and eliminates forged degrees and fake certifications through instant and automated authenticity checks.

6.7 Long-Term Reliability

- Credentials remain **permanently accessible** and verifiable, eliminating the risk of loss, damage, or degradation associated with paper-based certificates.
- Provides a **future-proof** solution that can evolve with technological advancements while maintaining historical academic records.
- Enables lifelong learning records, allowing individuals to maintain a consolidated and verifiable academic portfolio over time.

7. CHALLENGES

7.1 Adoption Resistance & Institutional Hesitation

- Many educational institutions and employers are unfamiliar with blockchain technology, leading to reluctance in adoption.
- Transitioning from traditional credentialing systems to blockchain-based solutions requires significant changes in infrastructure and workflow.
- Concerns over regulatory compliance, legal recognition, and standardization slow down widespread implementation.

7.2 Scalability & Performance Issues

- Blockchain networks, especially public ones, face scalability challenges, including slow transaction speeds and high processing costs.
- Large-scale academic credentialing systems require efficient solutions to handle millions of credentials without performance bottlenecks.
- Ensuring real-time access and verification while maintaining security and decentralization remains a technical challenge.

7.3 Privacy & Data Protection Concerns

- Although blockchain provides security, improper implementation can expose sensitive student data to unauthorized parties.
- Compliance with data protection regulations such as GDPR and CCPA is essential, requiring careful management of personally identifiable information (PII).
- Decentralized identity solutions like Zero-Knowledge Proofs (ZKP) and Self-Sovereign Identity (SSI) must be optimized to enhance privacy.

7.4 Interoperability with Existing Systems

- Integrating blockchain with legacy academic databases and institutional verification systems requires technical modifications.
- Lack of universal standards for blockchain-based credentialing can lead to fragmentation and compatibility issues.
- Collaboration between governments, educational institutions, and blockchain developers is necessary to establish a unified framework.

7.5 High Initial Implementation Costs

- Setting up a blockchain-based credentialing system requires investment in technology, infrastructure, and staff training.
- Institutions with limited budgets may struggle to allocate resources for blockchain adoption despite its long-term benefits.
- Developing and maintaining blockchain solutions, including smart contracts and secure identity management, requires skilled professionals.

7.6 Legal & Regulatory Uncertainty

- Many countries lack clear legal frameworks for blockchain-based academic credentials, creating uncertainty in recognition and enforcement.
- Establishing regulations for digital credential issuance, verification, and dispute resolution is essential for legitimacy.
- International cooperation is needed to standardize blockchain credentialing across borders.

7.7 Digital Divide & Accessibility Challenges

- Not all students and institutions have equal access to digital infrastructure, limiting blockchain adoption in underprivileged regions.
- Dependence on internet connectivity and digital literacy can create barriers for individuals unfamiliar with blockchain technology.
- Efforts are needed to ensure inclusivity and accessibility for all stakeholders, regardless of technical expertise or financial resources.

Despite these challenges, continuous advancements in blockchain technology, policy frameworks, and institutional collaboration can pave the way for a **more secure, efficient, and universally accepted academic credentialing system**.

8. CONCLUSION

Blockchain technology presents a **transformative solution** for academic credential management by offering an immutable, decentralized, and tamper-proof record-keeping system. By leveraging **cryptographic security, decentralization, and automation**, institutions can ensure the integrity of academic records while **eliminating fraud, inefficiencies, and administrative burdens**.

This implementation enables **instant verification**, reducing delays in admissions and recruitment while enhancing cross-border recognition of credentials. The adoption of **Self-Sovereign Identity (SSI) and Zero-Knowledge Proofs (ZKP)** further empowers students with greater control over their personal data while ensuring compliance with global data protection regulations.

Despite challenges such as **scalability, regulatory alignment, and adoption barriers**, the long-term benefits of blockchain in education far outweigh the obstacles. With continued advancements in blockchain interoperability and educational standardization, this technology is poised to become a **cornerstone of future-proof academic credentialing**.

By integrating blockchain with **existing educational infrastructure**, institutions can create a **secure, transparent, and globally accessible** academic ecosystem. As adoption grows, this innovation will reshape the future of education, fostering **trust, efficiency, and lifelong learning accessibility**.

9. SDG's ADDRESSED

9.1 SDG 4: Quality Education

- Blockchain fosters **equal access** to verifiable educational credentials, reducing fraudulent certifications and ensuring fair recognition of academic achievements.
- Enhances **educational mobility** by enabling cross-border recognition of degrees and certifications, supporting lifelong learning.
- Reduces administrative burdens for institutions, allowing resources to be redirected towards improving education quality.

9.2 SDG 8: Decent Work and Economic Growth

- Ensures **transparent and credible hiring** by providing employers with instant access to verified academic records, reducing recruitment fraud.
- Facilitates **skill-based employment** by supporting blockchain-powered digital resumes that showcase verified credentials and certifications.
- Encourages **inclusive economic growth** by eliminating barriers to employment due to credential verification delays.

9.3 SDG 9: Industry, Innovation, and Infrastructure

- Promotes **technological advancements** in credential management through decentralized verification and secure digital identities.
- Enhances **institutional trust and efficiency** by integrating blockchain with existing education and employment infrastructures.
- Encourages investment in **innovative digital solutions** that modernize traditional administrative processes and improve global academic standards.

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11.APPENDIX A

https://drive.google.com/drive/folders/1oHFZX1jmIosXM0o0qVEhbIxPUMy2rP92?usp=shring