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ENHANCING ACADEMIC TRUST AND ACCOUNTABILITY: A SCALABLE BLOCKCHAIN SYSTEM FOR CREDENTIAL VERIFICATION FOR EDUCATION

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Abstract

This study explores the design and implementation of a blockchain-based system to enhance trust, transparency, and security in academic credentialing. Motivated by the growing distrust in centralized institutions and the inefficiencies of traditional credential verification processes, the research leverages the immutability, decentralization, and transparency of blockchain to develop a tamper-proof mechanism for academic record storage and validation. Using the Ethereum Sepolia test network and real-world student performance data from the Open University Learning Analytics Dataset (OULAD), the system securely issues, verifies, and revokes academic credentials through a custom smart contract developed in Solidity. Each credential is hashed using SHA-256 to ensure student privacy while enabling public, real-time verification. The implementation was conducted in a Google Colab environment using Web3.py and Infura, with batch processing mechanisms and a Web3 interface for seamless interaction. Empirical results reveal performance patterns across modules and highlight opportunities for academic intervention. The system not only demonstrates operational feasibility but also offers a scalable, interoperable, and ethical framework for higher education institutions to combat credential fraud and enhance institutional accountability. Future work will focus on privacy-enhancing cryptographic integrations and decentralized identity standards to further solidify blockchain's role in education.

Keywords: Blockchain, academic credentials, smart contracts, Ethereum, credential verification, transparency, decentralization, educational trust systems, Web3

1. Introduction

Trust is being lost in both traditional institutions and in general in online middle-parties. Blockchain technology in particular has been touted as a potential solution, since it is said to eliminate the need for trust between parties[1]. All blockchain and all its numerous applications are saying, we must have faith in the authority of a technological system that can never be altered instead of having faith in the authority of centralised institutions that we do not believe in. Whatever the purpose of a public blockchain, it accomplishes it appropriately,

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removing the principal-agent issues that emerge in circumstances of trust, such as moral hazard and shirking. On this basis, blockchain has been called a trustless or trust-free system. Originally, the blockchain technology was created to be the platform on which cryptocurrencies like Bitcoin would be based. And since that time, it has been demonstrated to be a multi-purpose instrument in any application beyond finance.

Due to the decentralisation, security and transparency, blockchain can be used to change numerous aspects. By example, it could be used to address long-term concerns in such areas as credential verification, maintenance and protection of intellectual property, academic records.

Keeping record of who has cleared the courses required to graduate in higher education is a bit of a chore and the traditional methods of doing things are not only time-consuming, ineffective and prone to error and/or fraud. Most of us find blockchain technology a sensible approach as it provides us with a means of recording and verifying information that is secure and immutable and that with some chances of eliminating cheating, enhancing transparency. Bloodchain can be used to write digital transcripts and diplomas so that universities, graduates, and the companies where the student is employed can authenticate academic credentials without involving third parties. In addition, some administrative and personalised learning purposes could be automated by smart contracts and decentralised learning platform as well[2].

The traditional approach to teaching is that we have centralized power and paper - and now the digital age is causing a great deal of upset to that area. With the entire technological potential of modernity being turned towards blockchain, artificial intelligence (AI) and quantum cryptogra!phy, we have a once-in-a-generation chance to reconsider the very concept of what educational data storage, control, and security is. The cryptocurrencies were conquered by blockchain. Since then it has grown to become a general-purpose workhorse with possibilities stretching far across the board. Regarding education, blockchain has provided a decentralized and irrevocable database where all grades, certificates, and qualification documents could be securely stored and verified. With blockchain, individuals will not require middlemen and centralized regimes to ensure that they had and could control their education data. This will reduce the risk of these issues like certificate fraud, and unnecessary changes. Blockchain is used to make the checking processes transparent and irreversible so that the school systems can be trusted and held accountable. These quantum computing inventions have occasionally posed a security risk to the cryptographic foundations of blockchain, despite blockchain being a powerful technology to ensure data integrity. One of the biggest threats to the cryptographic algorithms today is quantum computing and what will the blockchain systems do about it? Another solution to this is also in the implementation of the quantum-safe cryptography solutions to the blockchain-based education systems to ensure their safe and trustful future. Educational processes may be made more efficient and effective by technologies like AI and blockchain. AI software is capable of doing a variety of things, including checking credentials and marking grades. It saves on administration and makes the job that needs to be done in the schools quicker. An executable contract: AI-powered smart contracts automatically carry out predefined functions based on whether a given set of conditions is met. AI-based smart

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contracts can help schools enforce terms of academic honesty, issuing of credentials and other terms of contract in clear and decentralized manner.

Overview of Blockchain Technology

Blockchain is an open, distributed ledger that can be used to record transactions between two parties efficiently and in a verifiable and permanent way. As suggested by [3] blockchain was originally developed to support the transfer of bitcoins but has expanded to offer advantages across multiple industries like healthcare, finance, supply chain, and education. The basic features of the blockchain such as immutability, decentralisation transparency and security are some of the reasons why blockchain is considered to be a useful tool to solve issues regarding data management, validation issues etc.

Key Features of Blockchain

Blockchain technology possesses several fundamental characteristics that make it a transformative innovation in data management and digital trust. These include **decentralization**, **immutability and security**, and **transparency**.

- **Decentralization**

The outstanding feature of Blockchain is decentralization. Contrary to the traditional mechanisms where information is processed by a central body and transactions are authenticated, the blockchain paradigm is such that all transactions are authenticated in a transparent, trustless P2P network by all members of the network, who are known as nodes. It eliminates middlemen, and as such, there is one fewer step that intermediaries can take to make everything a mess. The blockchain also makes the system stronger by eliminating the central node and reducing the chance of controls, corruption or failure. As mentioned in [4], this decentralized framework can strengthen efficiency and create trust among the network participants.

- **Immutability and Security**

The other characteristic of blockchain is immutability. Once a transaction has been stored and validated, it cannot be undone or changed or deleted on the blockchain. Any change to one block would need to change all that follow, as well as the agreement of the network majority, and is therefore computationally accurate. This aspect makes blockchain the most suitable option, to be used in the application, requiring data permanence and integrity, such as law agreements, medical history, and diplomas. Then the network state is highly secure due to highly developed cryptographic algorithms, due to the blockchain, and we are well protected against other unauthorized access, since in this case only, the trusted sources can access the data. Since [5] becomes possible due to the use of public-key cryptography and due to the mechanisms of hashing, which is used to protect data, then blockchain is an efficient solution to the preservation of online records.

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- **Transparency**

Blockchain is transparent, which implies that transactions and data in general can be accessed by any participant of the network. All transactions are recorded in a shared or public ledger (depending on the type of a blockchain- public or private) and can be viewed by all the involved nodes. This openness helps in accountability, and creates confidence among its system users, particularly where data integrity and auditability are among the highest ranking priorities. As demonstrated by [6] and the transparency plays a key role in fields like supply chain management, financial services, and academic processes where all the participants need to trust that records are valid. Transparent operations also help minimize misconduct because everything is made visible, and everything is made verifiable at the moment of occurrence.

Blockchain Beyond Cryptocurrencies

Blockchain has applications beyond finance, but is most closely associated with cryptocurrencies such as Bitcoin. In order to prevent fake degrees and certificates, blockchain technology is being researched in the education sector to be used to award, preserve, and verify academic credentials [7]. More potential blockchain applications are intellectual property protection in academic research, transfer of students between universities and education records. By enabling the execution of smart contracts (which are self-executing contracts having the terms of the agreement between parties directly written into code), blockchain may also be the solution to completely reform administrative processes in higher education [8]. Such contracts can reduce administrative overhead and enable efficiencies by automating things such as tuition payments, scholarship payouts and course registrations. Blockchain is a game-changing technology, but its adoption outside the financial world is in its early days. However its wider use is limited by technical challenges such as scalability and energy usage.To maximize the use of technology in learning and education sector, there are two important issues to address, which are how to connect blockchain with the existing systems and how to ensure the compliance with ensuring data protection regulations_INF and cyber-security_DOJ (2019).

Applications of Blockchain in Higher Education

Blockchain technology has the potential to revolutionize many facets of higher education, especially those that require transparent, safe, and impenetrable record-keeping. Blockchain has several potential uses in higher education, ranging from managing student records and credentials to decentralizing learning systems and safeguarding intellectual property.

- **Verification of Degrees and Credentialing**

One of the most significant use cases of blockchain in higher education is the issuing and validation of digital credentials. Diplomas and credentials are and example of conventional ways to validate academic assets, but can be cumbersome and inefficient and are open to fraud if not completely verifiable [9]. Through tamper-proof digital diplomas and certificates held on a blockchain, employers can more conveniently authenticate this academic achievement of a student .This decentralised model also turns students into agents by giving them control over their credentials, and allowing them to share verified documents with anyone, anytime,

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without intermediaries. The immutability of blockchain offers a reliable and safe way to ensure the history of academic achievement is maintained, because once the credential is issued it cannot be altered. The use for blockchain based certificates are already being tested by some universities, like the Massachusetts Institute of Technology (MIT) (MIT News, 2017).

Transcripts and Academic Records

Blockchain can help in efficient management of academic records. Retention of student records has always involved complex processes leading to errors, delays and loss of data - especially when students transfer between universities. Through implementing a safe even decentralized setup, universities can maintain records on a blockchain such that grades, academic achievements, and other vital information are stored in an immutable, verifiable database (Chen et al., 2020). It would be easier for students to switch colleges, as each could pull down the student's entire academic record, without intermediaries or additional verification. JG Block chain ability to provide detailed, tamper-proof visualization of a student's academic journey, along with the convenience of transferring the information, could potentially encourage lifelong learning and credential stacking (in which students earn endorsed micro-credentials or badges throughout their careers) (Garg and Gupta, 2019).

- **Smart Contracts for Administrative Processes**

Using blockchain technology to implement smart contracts, which are self-executing contracts where the terms of the agreement are automatically written in code. Smart contracts could automate many of the administrative tasks involved in higher education, accelerating the process and improving upon it. For example, smart contracts may be used to manage out-of-course registration, scholarship allocation, and tuition disbursement. The payments or funding can also be automatically executed by a smart contract when some conditions are fulfilled, e.g. the successful completion of a course or a grade. This enables the automatic and transparent discharge of the contractual obligations and the saving of the overhead of the administrative work too [10]. Additionally, educational resources shared between students and universities can also be recorded in smart contracts, thus, removing all the manual record-keeping processes.

Research Questions:

- How can blockchain be applied to store and verify academic credentials?
- What benefits in trust and transparency does it offer over traditional systems?

2. Literature Review

Blockchain technologies are being supplanted by new financial records, which are decentralized, both in terms of processing transactions and smart contracts [11]. They appreciate how decentralized registries are being re-distributed, and how smart contracts are questioning the automation and securitization of financial and legal processes. Their use in banking circles is focused, but the result is very applicable to education systems where secure record-keeping and automated verification of credentials is becoming more and more important. To make the paper more relevant to academic credentialing infrastructure, it

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proceeds to build an intuition of how blockchain can bring credibility to online systems and fewer transaction frictions to it.

The suggested new system [12] is called Kudos, a blockchain-based, decentralized, system, which allows to control and access education records, reputation and rewards. The focus of their article is how students can share and receive academic success across institutions through blockchain-authenticated credentials. The authors believe that enabling the learners to control their own data and reputational capital is also important in helping them to maintain a lifelong learning journey. The creation of such a model then merely preconditions the creation of blockchain-controlled academic systems by merely showing how academic evidence can be issued and verified and gathered in a secure way that does not require the cooperation of current centralized authorities.

This paper is a systematic introduction to blockchain, its underlying mechanisms, the properties of various types of blockchains (i.e., public, private and consortium) and security properties, as outlined in [13]. Yaga et al. explain consensus protocols, ledger (blockchain) structure, applications, and the drawbacks and dangers of implementing blockchains. Their objective analysis would prove particularly useful in academic settings, where degree institutions are attempting to discover the optimal mix of security, privacy, and regulation rules, by utilizing blockchain to authenticate credentials. It is a reference document on the responsible and standards-based integration.

[14] about blockchain principles, consensus algorithms and new developments. They offer a taxonomy of the blockchain development out of the cryptocurrencies into more generalized views (data integrity and decentralized trust systems). They emphasize its applicability to any industry requiring records to be transparent, secure, and immutable due to the fact that blockchain is reportedly highly transparent and can never be amended. In an education context, our findings do support a role of blockchain as a core technology to base tamper-proof credentialing systems, and indicate the necessity to build scalable and energy-efficient solutions in future.

this is the first research that suggests the structure of placing blockchain in charge of the personal data, through a blockchain-based decentralized architecture model including an off-chain storage. Zyskind et al. support the idea of user data ownership and propose the technical architectures to implement it in a privacy-preserving and secure manner. Their work is especially important to academics provider, as the information students exchange is highly sensitive and therefore must be designed to be private. The paper forms the foundation of a safe implementation of credential hashes and the foundation of decoupling data storage with the verification protocols in blockchain-based education solutions.

3. Research Methodology

- **Research Design Overview**

This study follows a **Design Science Research (DSR)** methodology combined with **quantitative data analysis** to develop, implement, and evaluate a blockchain-based credential

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verification system. The methodology is divided into five key phases: data acquisition, preprocessing, blockchain architecture design, system implementation, and evaluation.

- **Data Source and Description**

The study utilizes the **Open University Learning Analytics Dataset (OULAD)**, which is openly accessible and widely used for educational data mining. It is hosted on Kaggle at: 📍 https://www.kaggle.com/datasets/open-university-analytics/oulad

This dataset contains detailed academic records of 32,593 students across various modules and presentations. The relevant files used for this research include:

- studentInfo.csv – demographic and performance data
- studentAssessment.csv – students' assessment scores
- assessments.csv – assessment type, weight, and schedule
- courses.csv, studentVle.csv, and vle.csv – not used in this implementation

- **Data Preprocessing and Cleaning**

In order to construct this full and un-siloed credential database, the studentAssessment. the csv file was combination first with assessments. csv where id_assessment is shared as a common key. After that this intermediate result was again joined to studentInfo. csv using the keys id_student, code_module, and code_presentation. The resulting dataset was a fine-grained view of student-level data, including things like the nature and weight of assessments, individual student scores, and the result for each student at the end of their academic journey.

Missing score or weight values in the data cleaning process were deleted to keep the integrity of data for analysis. Furthermore, students with final result as 'Withdrawn' were also omitted from the dataset in order to concentrate on the academically related outcomes. The date_submitted field was kept, and was assumed to be a reasonable proxy for the date the credential was issued with respect to the start of the course, thus enabling time-based analyses of relevance..

- **Feature Engineering**

A new variable weighted_score was calculated for each assessment:

$$\text{weighted\_score} = \frac{\text{score} \times \text{weight}}{100}$$

To be able to produce meaningful insights, the masterset was further aggregated by student by module. Summary: The aggregation included the calculation of final_weighted_score which was obtained by summing all assessment scores for a student (weighted as per the assessment weights). The most_recent_submission_date had been found for each particular student-module combinations and was used as an approximate for the credential issue date, representing the last recognized learning activity. The resulting data set included the main

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variables: id_student, code_module, code_presentation, final_weighted_score, final_result, and latest_submission_date. This format enabled both a summary of each student's achievement in a given module to be briefly and thoroughly represented.

4. Blockchain System Design and Implementation

- **Overview of System Architecture**

The blockchain-powered credential verification solution arose to address pain points within academia, such as falsified credentials, slow verification systems and the absence of a trusted global system to check academic records. Using the blockchain, the system guarantees that academic records are not compromised, are transparent and can be verified at institutions and workplaces. In particular, the system leverages the Ethereum blockchain (by storing cryptographic hashes of academic credentials generated from education performance records/genuine data) to keep privacy and ensure authenticity. The architectural design of the system is divided into three principal layers, all contributing significantly to the operation of the platform. In the first layer, the Data Layer, a student performance data is preprocessed and prepared based on the Open University Learning Analytics Dataset (OULAD). This aggregated and sanitized data is the basis for the credential generation. The second layer, the Blockchain Layer, is based on Ethereum blockchain (Sepolia Test Network) and connected and inter-fused using Infura and Web3. py. This is where credential hashes can be stored safely, and distributed in such a way that they cannot be modified or forged once they have been issued.

The third section is Application Layer and is a smart contract written with Solidity. This agreement is under the logic of issuing and verifying credentials. It is implemented on the Ethereum testnet and communicates with Python-based scripts of Google Colab that can be found on the interface web3. py. Such a multi-layered design is required to ensure not only the security and impossibility of changing but also the cross-functionality of educational data, blockchain infrastructure, and end-user applications. All this makes it a secure system that is potent and even capable enough to query contemporary credentials.

- **Data Preparation and Credential Generation**

As the credential verification depended on the blockchain, the source of the academic performance information was the Open University Learning Analytics Dataset (OULAD). Especially the last three CSV files of the data set were selected: studentInfo. csv, studentAssessment. csv and assessments. csv. This was brought into Google Colab and ran in Python using the Pandas library to obtain an ordered collection of data to work with. A number of significant pre-processing steps were implemented at the data preparation stage. Student assessment results were then matched with their assessment weighting by joining the studentAssessment table to the assessment table. csv with assessments. csv with id_assessment key. This allowed the weighted scores to be computed for any individual student assessment. That merged dataset was then joined into studentInfo. csv based on common keys: id_student, code_module and code_presentation in order to combine demographic information with final results. Rows with missing values were removed to maintain writing assessment integrity and informativeness. Furthermore, students who were recorded as having received a ‘Withdrawn’

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final_result were removed from subsequent analysis as they did not undertake the academic component and are, accordingly, not eligible to have a degree conferred. The final weighted average score (final_weighted_score) for every student for all combination of student-module has to be calculated by adding up all assessment scores weighted by their corresponding weights. For each student, their most recent date of an assessment submission was kept as the issue_date, which acted as a proxy for the timestamp for when the credential was issued.

A distinct credential hash was then calculated on each student to preserve privacy, without compromising integrity or uniqueness of the credential data. This was accomplished by using the SHA-256 cryptographic hash of studentid + codemodule + codepresentation + issuedate. It is a protocol in which all hashes are irreversible, deterministic, and uniquely linked to an academic record without revealing any sensitive information. The result of this operation was a formatted DataFrame, credentialdf, that contains all the fields needed to make a registration with the blockchain. The properties of this DataFrame included: columns t = credentialhash, codemodule, codepresentation, finalweightedscore, issue date The above fields comprise a provable, privacy-protecting academic certificate, ready to be published on the blockchain network.

- **Smart Contract Design**

At the core of the credentials verification using blockchain, system is a custom smart contract named AcademicCredential written in Solidity and running on the Sepolia Ethereum test network. This is the decentralized agreement whereby academic credentials are sought, validated or canceled. The architecture of Ethereum also ensures that a credential asserted on-chain is tamper-evident, tamper-proof and publicly verifiable.

The hashed academic credentials are stored in at least one key of 32 bytes at the heart of the smart contract in the form of a MAPPING architecture. The hashes are computed over a unique student-level data set using the SHA-256 algorithm and can be anonymized without information or linkage loss. Each password in a record is addressed with the resultant hash encased in a structure, the structure being:

- code_module: the academic module in which the student was enrolled,
- code_presentation: the academic term or session,
- final_weighted_score: the student's final aggregated performance score,
- issue_date: the date on which the credential was issued (based on the latest assessment submitted),
- issuer_address: the Ethereum address of the issuing authority,
- status: a flag indicating whether the credential is **valid** or **revoked**.

The smart contract exposes several **critical functions** to enable secure and transparent credential lifecycle management:

1. issueCredential() – The authorized issuer can use this method to store a new credential onto the blockchain. It takes the hash of the credential and its metadata and saves it into the

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contract mapping (line 8). No one can call this function but the designated issuers that protect the integrity of the credentials.

2. verifyCredential()- Such a public view function will enable any third party Players (E.g Employer, Institutions) to check the credential according to the hash and metadata. This is achieved by querying the blockchain directly, which bypasses the manual verification and simplifies the protocol and helps reduce the credential fraud.

3. revokeCredential() This function allows the issuing authority to revoke a credential (e.g., in situations of a mistake, fraudulent acts, or changes from an administrative point of view). The status of the credential is then permanently recorded on-chain, and subsequently any verifiers would need to account for that revocation when verifying the credential..

The inclusion of such functionalities is aimed to enforce data integrity, traceability, and user autonomy in the AcademicCredential smart contract. Crucially, as every record exists on the blockchain, no record is tampered with._stamp can be accessed anywhere, making it a scalable solution for cross-institutional proof of credentials. The design meets present day needs for secure digital certification, and provides a strong alternative to paper-based or centralised credential systems.

- **Web3-Based Implementation via Google Colab**

An end-to-end implementation of the proposed blockchain-enabled academic credential verification system was further implemented under Google Colab to test its practical usability. This testnet environment with modular Web3 stack was used to mimic actual usage and deployment. The elements and implemented tools of such a prototype design are given as following and illustrated as below:

Component	**Tool Used**
Blockchain Network	Ethereum Sepolia Testnet
Interface Library	Web3.py
Deployment Endpoint	Infura HTTP Provider
Wallet Integration	Testnet Wallet via Private Key
Ledger Simulation	SHA-256 Hashing and Verification

Table 1: Tools Used

The system utilizes the Web3. py library to connect to the Ethereum Sepolia test network using the Infura HTTP provider. The ABI and contract address of the deployed smart contract were introduced to the environment, allowing interaction with the blockchain. Safe transaction signing was done with a private key associated with a testnet wallet so verifying, issuing, revoking credentials as per smart contract logic were made possible.

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In addition, we simulated the on-chain database record of credentials using the SHA-256 for the hash algorithm in order to hash and de-identify the sensitive academic information while maintaining its distinct value and its ability to be verified. This prototype is a proof-of-concept, showing the investment, viability and cost-effectiveness of the envisioned web3-enabled credential management framework within a cloud-based IDE.

- **Batch Credential Issuance Workflow**

To scale and make credible issuance process more efficient, a batching workflow for issuance was developed using Python and Web3. py library. This function also makes it possible to deploy several academic credentials to the Ethereum Sepolia test network in a sequential manner in a single execution pass. The function we derived runs a sequence of operations to guarantee the sound and auditable issuance of the application-specific credential on each link of the batch. The workflow contains the steps:

1. Hash Conversion: Each academic qualification is hashed using the SHA-256 hash function and the output hash converted to a fixed-size representation of bytes32 that can be stored in the mapping structure of the smart contract.

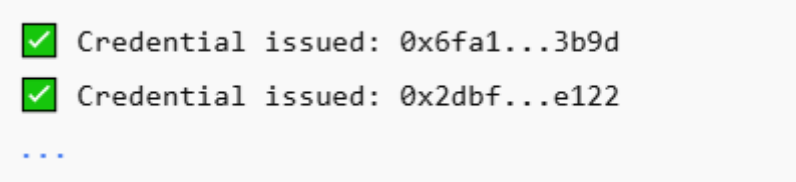
Transaction Construction: A credential is programmatically built as a transaction (by calling the issueCredential function implemented in the deployed smart contract). This service uses the credential hash, the metadata.

Transaction Signing: The constructed transaction is signed, locally, using the assistance of the private key of an already created test account. This provides some credibility to the transactions and enables them to be implemented in the blockchain.

Broadcast to Network: The signed version of the transaction is submitted to the Ethereum Sepolia testnet through the Infura HTTP provider which establishes a connection to the decentralized ledger.

5. Transaction Confirmation: The operation is the programmatic monitoring of the transaction being received to ensure that it has been added to a mined block. Every receipt is authenticated to counter that the credential has been properly stored on-chain.

This batch processing approach not only reduces the operational overhead associated with individual credential submissions but also serves as a robust framework for institutions intending to deploy large-scale credential issuance mechanisms in real-time blockchain environments.



- **Confirmation and Denial.**

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The integrity assurance and the post-issuance control of the system are based on the verification and revocation functionalities. The two functions are both implemented on the same Web3 interface and use the transparent and immutable infrastructure of Ethereum to ensure a credible academic credential lifecycle.

- **Verification Process**

Credential verification is realized by calling the verifyCredential(bytes32 hash) functionality on the deployed smart contract. The input to this operation is a hash of the credential (generated by the issuer through the use of the SHA-256 algorithm at the time the credential is issued) and the metadata stored on the credential is read on-chain. Upon execution it provides back the important information such as:

- **code_module**: The academic module in which the credential was earned,
- **final_weighted_score**: The student's overall performance,
- **issuer_address**: The Ethereum address of the issuing authority,
- **status**: A flag indicating whether the credential is active or revoked.

This process enables any external entity—such as academic institutions, employers, or credential holders—to independently verify the legitimacy and current status of a credential without relying on centralized intermediaries. The public accessibility of the blockchain ensures transparent and tamper-resistant validation.

➢ **Revocation Protocol**

Credential suspension may be required in cases where there is an error, the procedure or fraud has been corrected. This is achieved by invoking the revokeCredential(bytes32 hash) function that can be invoked by the issuing account that granted it in the first place. It will update the state of the credential in the data structure of the smart contract when called and revoke the credential. When you possess an invalid credential, repeated verification will also report this change of status.

The combination of public verification and issuer-controllable revocation is the basis of the accountability, auditing and compliance with real-life academic governance requirements of the credentialing system. It also demonstrates how the promise of decentralized technology can support end-to-end lifecycle management of digital academic credentials.

- **Security and Integrity**

The blockchain-based academic credentials verification system suggested in this paper revolves around data security, privacy security, and system security. No direct student information that can be personally identified is ever made public as all on-chain credential information is represented only by cryptographic representations. The hash algorithm has been adopted as SHA-256, where all passwords are not encoded in the same way, hence, anonymity and traceability is achieved without any sensitive academic or personal information being disclosed about the students.

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These hashes are irreversible and immutable when documented by the nature of the Ethereum blockchain. To ensure that manipulation or falsification of credential information is computationally prohibitive and can be quickly detected, 5.3 The smart contract is constructed using crucible verification processes to prevent instances of double entry and issuing unauthorised credentials. It is these safeguards that cause the blockchain to be clogged with fraudulent or redundant credentials. A credential can only be revoked by the issuing entity (typically the university or academic institution where the credentials have been issued) having a policy to revoke credentials. This is constrained at the smart contract level, to avoid interference by outsiders and fraudulent revocation. Generally speaking, the system design architecture makes us remember about the idea of decentralization and offers security, integrity and institutional responsibility.

- **System Advantages**

Different particular advantages of checking academic credentials with the help of the blockchain depend upon its technological organization and overall intention. Their most successful feature is that blockchain is immutable, meaning that a credential added to the distributed log is impossible to alter or delete. It is a natural attribute that will come in handy in this relationship in ensuring there is no tampering of the data and in ensuring the integrity of the scholastic records across generations. The other huge advantage of decentralization is that it does not involve the issuance of credentials by one centralized person. Decentralized network control reduces risks of single points of failure and institutionally biased control, and maximizes transparency and resilience.

It also has the instant validation feature wherein the employers or the other institutions of learning or even the learners could access the academic records on-the-fly in real-time wherever the learners are located. This ubiquitous connectivity establishes envy-of-credibility immediately and assists in eliminating much of the dead air that is inherent in the traditional credential validation process. It is privacy by design system architecture. Not only can sensitive personal and academic data be stored in a secure off-chain manner, unique records are generated, which can be verified due to the cryptographic hashes being stored in one location on-chain. The approach provides privacy-transparency trade-off in which principles of ethics and privacy are applied in order to control the process by which the digital identity is managed.

5.Results

The graphic representation of the academic performance of the scores of Pass, Fail and Distinction, gives some handy information regarding the overall tendency of the academic performance of the total population in question. Over 13,000 students were awarded a Pass which shows a huge percentage of students were able to achieve the minimum academic standards needed of their modules. One conclusion of this trend is that the way in which instruction is designed, the standards used to measure progress, and the guidance provided are moderately useful in helping students to progress through the sequence of courses offered in the curriculum. In comparison, a few 5,800 students received a Fail. Also to be noted is that it has a rather high failure rate, possibly due to the difficulty of some of the modules, absence of

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academic support, or decrease in the level of activity of the students. These findings support the significance of individualized interventions (ie, early academic advising, individualized performance feedback, more tutorial support) to help academically at-risk students succeed.

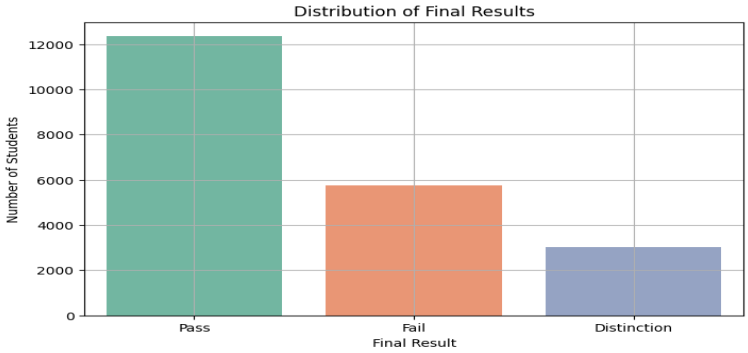

Figure 1: Distribution of final academic outcomes among students in the dataset

At the other end, there are a few 3,000 students who got a "Distinction" which is the students who have very high academic standards. Since the population of this group of students is relatively small, it suggests that only a small percentage of students who are highly driven and/or academically strong are able to achieve distinction-level performance. This could be as a result of many factors like past academic history, self-regulation, intelligence and availability of task relevant resources. The unequal spread of results speaks to a system that is efficient enough in delivering the academic fundamentals to the many, but in which excellence remains a more selective achievement.

Two of their modules, named DDD and CCC are high performance with a mean score over 110, students are better examined to or the module is easy to become high-score. E.g. Possible causes include more efficient means of teaching, more suitable types of assessment or more active students with a better impetus on these classes. BBB and GGG mean scores were lowest at below 60 on the other hand. It is assumed that this underperformance is caused by a set of academic challenges such as the development of more challenging content, the failure of linking the learning results with the assessment, and the absence of pedagogical or technical support. Also, low student attendance and the rate of dropouts are also possible in such modules and in most occasions it plays a huge role in determining the averages the student gets.

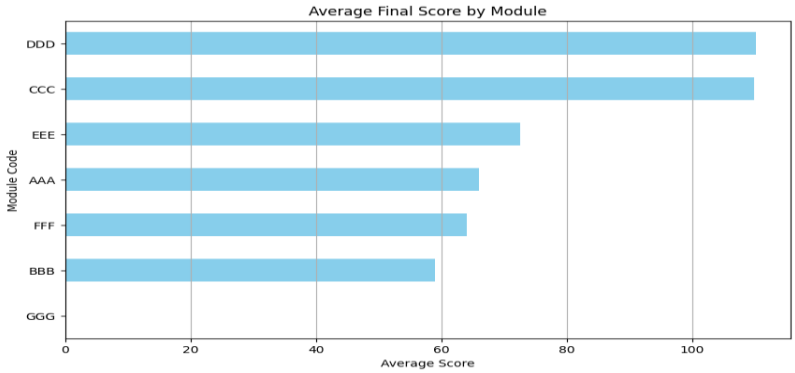

Figure 2: Average Final Score by Module

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The variability of the individualized pedagogical intervention remains noted based on the variability of module means. Some of the most effective modules may contain best-practice models of curriculum design and delivery. Conversely, low-scoring modules, will have to be re-tested so that specific obstacles to student achievement can be determined. The alternatives available to academic administrators might involve: curriculum revision, better teacher training, adaptive learning technology/additional support academic materials to those areas of weakness.

6. Discussion and Conclusion

- **Discussion**

This paper identifies blockchain as technology that has the potential to disrupt the educational credentialing system by providing a secure, decentralized, transparent way of storing and validating degrees. The creation and deployment of an Ethereum Sepolia test network smart contract system using real student performance data of the OULAD (Open University Learning Analytics Dataset) has demonstrated how academic credentials can be issued based on smart contract in a tamper-resistant way.

It is evident that the final results frequency distribution (Figure 1) was heavily biased towards Pass results with fewer in the Distinction range. Here it is connoted that though a large percentage of the student population did complete their education, excellence in academic achievement is uncommon at the superlative level. Comparatively, the study of average scores (Figure 2) in the modules revealed that there were single modules in which the average scores are constantly high or low and that has major implications in both designing the curriculum and in terms of teaching quality. The system has a design using cryptographic hashing over student performance records and a signed posting to a blockchain in the form of irreversible recording proofs. Using SHA-256 for creating a unique hash from each credential, the system protected students' privacy and allowed for the public verification of academic results. The features of the smart contract for issuing credentials were the issuance, verification, and revocation processes, which corresponded to the common lifecycle of academic records.Batched issuance was successfully developed by utilizing the Python and Web3. py when running in a Google Colab environment.

This reduces the need for employer verification and minimises the risk of credential fraud while eliminating the need for a centralised organisation to handle potential fraud. Moreover, with the introduction of a Web3 application layer, we are enabling real-time communication with the blockchain, which makes our system viable as a digital trust infrastructure framework in tertiary educational institutions.

- **Conclusion**

It has been demonstrated in this publication that it is feasible to construct a blockchain-based academic credentialing system, using both real-world education data and Ethereum smart contracts. The project demonstrates that the production of verifiable degree records by academia is possible without disclosing sensitive student information or at a negligible

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percentage of the administrative cost of conventional degree verification regimes. Technical architecture-- is built and implemented using open-source software (with Solidity, Web3. py- and Infura-is one example of a scalable pattern of introducing blockchain to the education sector easily accessible. Once the introduction of the google colab, the experimentation was easy and it had repeatability i.e. exploration, and application i.e. in academics. Comprehensively, this blockchain credentialing model is going to assist in overcoming some of the most critical challenges in the education field: trust, transparency, and data integrity. These could be as simple as the addition of zero-knowledge proofs to enhance privacy, or an inter-institution credential exchange based on the DID (Decentralized Identity) standard, or the creation of a student- and employer-facing decentralized application (DApp). The project is part of the course towards ethical and globally trusted academic records administration on scale.

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