Blockchain Based DApps for Education

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Blockchain technology has captured the attention of various industries due to its potential to revolutionize traditional systems through decentralization, transparency and immutability. This paper examines the emerging trend of integrating blockchain-based decentralized applications (DApps) into the education sector. With blockchain's distributed ledger system, educational institutions can achieve safe, secure and transparent management of student achievements, certifications and credentials. The paper presents the architecture of a system that enables students to build verifiable digital portfolios of educational achievements stored and shared securely using smart contracts and digital tokens. By harnessing the benefits and addressing the challenges of blockchain DAppps in education, we can pave the way for a truly transformative era in the learning experience of tomorrow.

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1 Introduction

Blockchain technology, initially tightly coupled with the financial sector, has witnessed significant advancements since the emergence of Bitcoin as a decentralized payment technology following the 2008 financial crash [1]. Ethereum, launched in 2015, has emerged as the second-largest blockchain platform in market capitalization and user adoption, primarily recognized for its smart contract capabilities [2]. Unlike Bitcoin, Ethereum introduced the ability to perform calculus in a loop and construct smart contracts, a concept initially conceptualized by Nick Szabo in 1996 as digitally specified promises between parties [3]. Contrary to their nomenclature, smart contracts do not resemble traditional contracts, explicitly specifying involved parties or consequences. Instead, they are immutable code deployed on the blockchain, allowing users to establish rules for various transactions beyond the financial sector. The potential for algorithmically encoding and enforcing traditional business contracts through smart contracts is substantial.

Furthermore, large enterprise applications often rely on complex, multi-layer redundant architectures to ensure security, making the paradigm behind smart contracts highly powerful. However, the widespread adoption and disruptive potential of smart contracts on the blockchain face challenges without established standards, best practices, and risk mitigation measures [4]. The lack of security provisions and fault handling and recovery capabilities for blockchain actors can impede the broader adaptation of smart contracts and hinder their potential benefits. In this article, we delve into utilizing blockchain decentralized applications (DApps) in Education, specifically focusing on integrating blockchain DApps to enhance educational systems. This paper aims to provide insights into how blockchain technology can revolutionize education by exploring potential benefits, challenges, and implementation strategies.

Moreover, the paper follows the limitations and potential risks associated with the implementation of blockchain in Education, including scalability concerns, privacy considerations, regulatory frameworks, and the importance of technological literacy among educators and learners. We also propose best practices and recommendations for educational institutions interested in adopting blockchain DApps, emphasizing the selection of suitable blockchain platforms, collaboration with stakeholders, and the significance of user-centered design. By contributing to the growing body of knowledge on the utilization of blockchain DApps in Education, this research aims to provide valuable insights for educators, policymakers, and researchers seeking to leverage the transformative potential of blockchain technology to enhance learning experiences and educational systems.

2 Edtech and the Hybrid Classroom Model

The educational technology, EdTech in short, represents the integration of technology in the educational delivery process with the aim of improving the student experience and learning outcomes.

Before the COVID-19 pandemic, Education primarily followed an offline and online modes dichotomy. However, the disruption caused by the pandemic compelled institutions to explore the untapped potential of online learning, leading to a paradigm shift. The convergence of offline and online learning modes has given rise to the hybrid classroom model, where students can engage in various ways, benefiting from the flexibility and customization it offers.

In his book, ”Metaphors of Ed Tech” [5], M. Weller explains that throughout history, EdTech has taken different forms. The first iteration of EdTech was radio, people believing that specialists would give lectures in front of crowds thus completely replacing teachers. Over time, this assumption has proved false, people still relying a lot on human interaction in the learning process. While it is unlikely that online learning will completely replace physical sessions, merging these two worlds has unveiled a synergistic effect that demands our attention. Our everyday lives become increasingly hybridized, with a seamless blend of physical and digital. One of the biggest drivers is the multimedia. People consume multimedia in various forms. With the hybrid model, students can alternate between physical and virtual attendance, adapting their learning paths to suit their individual needs.

Synchronous learning takes place in the classroom, together with the teacher. However, for various reasons, learning may not be at its highest intensity. Asynchronous learning occurs when the student can resume the information at his own pace. If, for example, the information is in the form of a video, on a platform, then learning becomes adjustable. Adaptive learning for each person is the holy grail of learning.

However, as with any technological advances, challenges follow. Sustaining high levels of student engagement in this attention driven economy remains a pressing concern. Educators must address the plethora of distractions that compete for students' attention and overcome the fatigue associated with extended online sessions.

The Internet has lowered many barriers to education, the biggest being cost. It has created an abundance of information, sources and courses formats. At the same time, however, it created a problem in terms of supporting the level of concentration and commitment for students.

Platforms such as MOOCs or Massive Online Open Courses, the largest being Coursera, have succeeded in democratizing education, managing to offer courses from prestigious institutions in America, at very low or even zero costs. However, a problem they face is that of retention. Less than 5% of those who participate in such courses finish. One of M. Weller's metaphors is that of "cool uncle" [5]. These platforms assume that they can do things better than traditional ones, but they face the same problem. The metaphor refers to the fact that the uncle will have the same problem as the parents possibly, or even others.

Blockchain technology has the potential to greatly increase the efficiency, transparency and security of educational systems by improving the verification, sharing and management of educational data and resources.

A few examples of universities already using a blockchain approach in education, as presented on their websites, are [15]:

- *Arizona State University* – an Ethereum blockchain is used to secure academic records storage improving the overall university transparency level.

- *Imperial College London* – blockchain technology is used for supply chain management to achieve a better traceability of goods and improved transparency.
- *MIT (Massachusetts Institute of Technology)* launched a blockchain based digital certificate issue system in 2015 named Blockcerts, allowing the students to receive secure digital certificates for academic achievements that can be easily validated for credibility.
- *Stanford University* – management of the student certificates and digital identity with the help of blockchain technology.
- *University of College London* – managing the student records and educational data in a secure way using blockchain.
- *University of Nicosia of Cyprus* introduced its own digital currency based on the blockchain in 2013; also, the payments for various taxes of the students can be made by using several cryptocurrencies, like bitcoin.
- *University of Melbourne* is using blockchain technology for the management of the digital certificates and digital identity of the students.
- *Open Source University* - decentralized platform managing credentials for academic achievements.
- *University of Malta* – secure sharing of research results among universities for an improved authenticity.
- *Swiss Federal Institute of Technology Zurich* implemented a DAO (Decentralized Autonomous Organizations) approach with the help of the blockchain for a transparent governance and decision-making system.
- *Sony Global Education* – blockchain oriented platform for universities allowing educational data to be securely shared with other institutions, applications and services.

Looking to the future, the integration of emerging technologies, such as augmented reality, virtual reality, and artificial intelligence, holds tremendous promise for further transforming the hybrid classroom. The traditional demarcation between offline and online educational modes has blurred, giving rise to a new paradigm: the hybrid classroom. Nevertheless, nowadays students, often called digital natives, still require guidance in navigating and making the most of the technological tools at their disposal.

3 The Challenges of Shifting to the Web 3.0

It is crucial to approach the development and adoption of Web 3 with a critical mindset, thoroughly evaluating its current technological constraints and limitations. The concept of Web 3, an open, decentralized, and permissionless Internet, has sparked intense debates regarding its viability and potential [6].

The first major challenge that Web 3 faces is the scalability of technology. Its practical implementation needs to improve in several aspects. Vitalik Buterin, the founder of Ethereum, has already pointed out some limitations while coining the term "blockchain trilemma". He explained how a blockchain can focus on two of the following 3: scalability, security and decentralization. For example, Ethereum, the second-largest blockchain per market capitalization, before switching to the Proof of Stake consensus protocol, could handle only 15 transactions per second, starkly contrasting the impressive 65,000 transactions per second processed by Visa. This significant disparity in transaction speed has been a break for massive technology adoption. The Ethereum decision to switch to a Proof of Work consensus mechanism from Proof of Stake is a trade between decentralization and scalability, given on the first for the ladder [7].

Furthermore, blockchains are affected by high costs and volatile cryptocurrency prices, transaction costs, and computing power. The fluctuation in prices results in barriers to entry for individuals and organizations looking for more predictable environments. While the principles of decentralization and increased user autonomy are appealing, the practical realities of limited transaction capacity and high costs must be carefully considered.

One significant obstacle to the widespread adoption of blockchain is the user experience. The success of any technological paradigm shift depends on its ability to offer tangible improvements and a better user experience compared to its predecessors. Ongoing research and development efforts are focused on scaling solutions for blockchains, such as layer two protocols and sharding, aiming to improve transaction speeds and reduce costs to overcome these challenges.

Blockchain promises easier collaboration, data sharing, and insights, but it also burdens users with navigating its complex systems. Only a few individuals possess programming skills or a deep understanding of smart contracts. To make Web 3 more accessible and user-friendly, a larger degree of abstraction in terms of tooling and products is needed. Users interacting with decentralized applications and managing their digital assets may encounter technical difficulties, security issues, or legal challenges. Ensuring adequate support systems are in place to address these concerns is vital for building trust and confidence among users.

Unlike traditional centralized systems, blockchain operates on a distributed network with decentralized decision-making and control. While this has advantages, such as increased security and resilience, it introduces complexities and uncertainties regarding governance structures and dispute resolution mechanisms. The blockchain community has faced governance crises in the past caused by unethical exchanges. Establishing transparent and inclusive governance mechanisms, addressing privacy concerns, and creating support systems for users are essential steps towards ensuring the successful adoption and equitable implementation of Web 3.

Furthermore, the ownership of files stored on an immutable blockchain becomes a significant concern. Once data is recorded on the blockchain, it becomes virtually impossible to alter or delete. While this feature ensures data integrity and trust, it also raises questions about privacy and the ability to remove or modify information in certain circumstances. These considerations become crucial in contexts where sensitive or personal information is involved [8].

4 Identifying Blockchain Use Cases

When evaluating the suitability and feasibility of integrating blockchain technology into various real-world scenarios, one should consider the key characteristics of blockchain technology, which are subsequently translated into specific use case attributes for independent assessment [9].

The complexity of education is underscored by a multitude of needs and peculiarities that demand our attention and comprehensive solutions. The core values of blockchain can fulfil many of the needs of the education industry.

Education involves several actors, apart from students, such as teachers, parents, tutors, administrators, and even entities in the after-market, such as recruiters, employers, and legislators. Blockchain was developed as a disintermediation and decentralization solution; hence, the consensus mechanism governing good functionality is the key to fulfilling all education stakeholders' needs.

Education is a long-term process that requires constant progress monitoring, record storage, and traceability. On the other hand, blockchain was conceived to store everlasting, traceable financial transactions. The storage of financial transactions or transactions of any other type is identical. The only downside is the cost. Data are relatively small in financial transactions: the transaction sender, recipient and amount. However, storing more complex data is much more expensive. With the implementation of some standards for NFTs, the solution was to store the hash of a transaction on the blockchain and the effective date to be stored outside the blockchain, possibly on another decentralized solution such as IPFS (InterPlanetaryFileSystem).

Education is often linked to social incentives and activity-based rewards. Blockchain has similar traits, such as built-in reward system for mining transactions. Education needs to remove bureaucracy and automate processes. Blockchain technology enables the implementation of smart contracts, facilitating the automation of processes governed by predefined rules.

Finally, education must be open, censorless and publicly accessible.

4.1 Records Traceability

One low-hanging fruit of education-based blockchain solutions is storing digital credentials on the blockchain. Blockchain-based platforms can enable the secure and tamper-proof issuance and storage of digital credentials and academic records. Any data that proves activity can be stored on the blockchain, from something more general like a diploma to something more granular like class attendance. The difference can only be made by storage costs proportional to the size of the data. The advantage of such a constant solution is the ease of tracking, auditing, and validating a credential by anyone, such as a recruiter.

4.2 Financial Transactions

Another obvious use case is payments that can be made with blockchain. Blockchain was thought to reduce transaction costs, especially for cross-border transactions. Education is very sensitive to costs. In addition, at the payment level, blockchain can be used for sponsorships, which in education can be scholarships or grants.

4.3 Enhanced Operations

A final aspect of education is that it must be distributed and adaptable. The DEFI (Decentralized Finance) [11] world came up with the concept of decentralized autonomous organizations (DAOs), organizations that can come up with improvements at the governance level. For example, they may come with voting rights, access to resources, and property rights.

5 Am Implementation of an NFT Diplomas

Tokenization is the process of creating a blockchain representation of a real-world asset. A token is a log in a blockchain that records information using cryptographic algorithms that ensure the security of the entire system.

Blockchain started as a digital representation of an asset: cryptocurrency, the difference being that cryptocurrencies do not have real-world equivalents. A token can contain almost any type of information or rights. In theory, anything with an ownership impact can be tokenized: from real estate properties to concert tickets. Some of the most successful examples come from the Defi (Decentralized Finance) world: the stablecoins. Stablecoins, such as USDT, are the tokenization result of a real-world asset: the US dollar. Their value is derived and pegged to their real-world counterpart. Therefore, there is a process of uniformization for token asset creation, depository, exchange and withdrawal. For example, the process of USDT token management involves depositing an equal number of US dollars into the Tether treasury vault, the company behind USDT. When exchanging USDT for a real-world asset, the company withdraws the amount from the treasury and burns an equal amount from the blockchain [11].

A digital token is achieved through smart contracts, which can withhold ownership information, such as the current owner or the history of the owners. Tokens can participate in different processes: they are produced through minting, destroyed through burning or transformed. Ethereum has standardized two major types of tokens: the fungible and non-fungible, for which they have produced two standards, ERC-20 and ERC-721. As smart contracts digitally represent tokens, they can receive discretional attributes, such as status and issue date. [12].

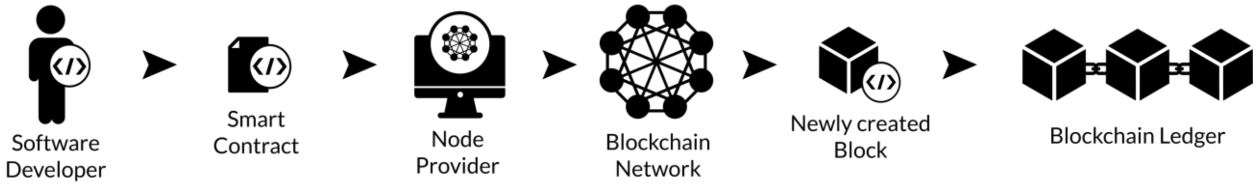

Fig. 1. Smart Contract Deployment Process

Figure 1 illustrates how creating a smart contract is a linear process: firstly, a software developer encodes the business logic into a contract representing an NFT, and then the contract is submitted to the blockchain through a node provider via a contract creation transaction. The node provider elects the transaction from a pool of newly created transactions and records it in a new block. In some situations, deployment can be done on a second layer or L2 blockchain. These side-chain solutions, such as Polygon, are intended to enhance scalability. Polygon, every once in a while, it, synchronizes with the main blockchain, that is, with Ethereum. Figure 2 illustrates the second layer deployment process.

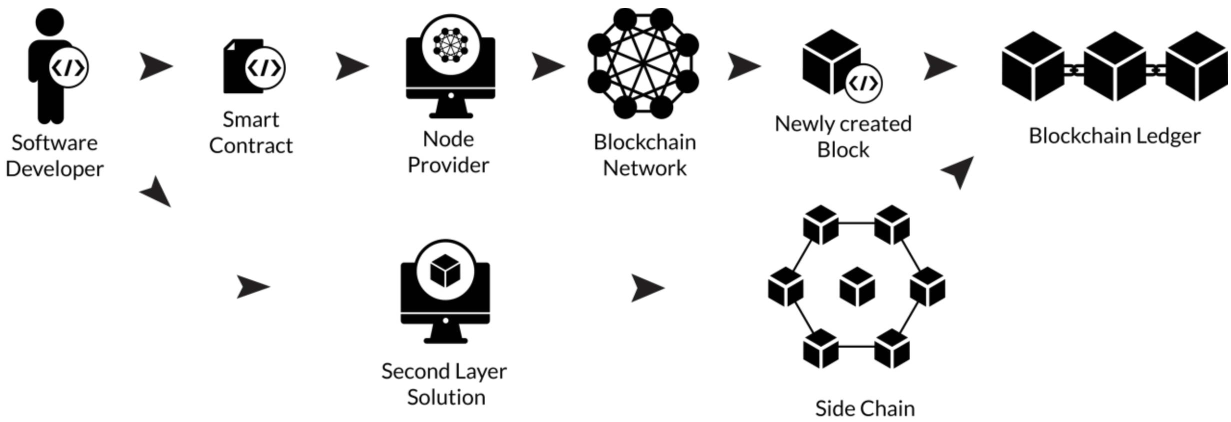

Fig. 2. Second Layer Deployment Process

In their purest form, diplomas or certificates are a unique type of NFT. They are non-fungible, hence not divisible, and each one is distinct per holder, making them irreplaceable. However, unlike art NFTs, they also possess certain unique traits. One is that diplomas and certificates are not intended for trading, so they do not possess monetary value.

When attempting to tokenize a real-world asset, two significant barriers emerge. The first, and perhaps most crucial, is the legal one: How can we ensure that the asset holds an equivalent value in the real world? In theory, anyone can create an NFT and claim to hold a degree from a specific issuing college. The creation process of smart contracts is open and public, but there must be robust legal enforcement for that contract to have legal consequences in the real world. However, if it is used for the purpose of additional separate verification, as in the case of diplomas, the legal aspect is less significant but still important.

The second important point is how to make and maintain the connection between the intrinsic value in the real world and the value of the blockchain. For material goods whose value is linked to a specific price, this can be achieved by linking the real-world price to the price on the blockchain. For diplomas or other assets that do not have a value, the binding must be done only through constant maintenance by the issuing entity. For example, the faculties must maintain or create to invalidate the list of graduates on the blockchain.

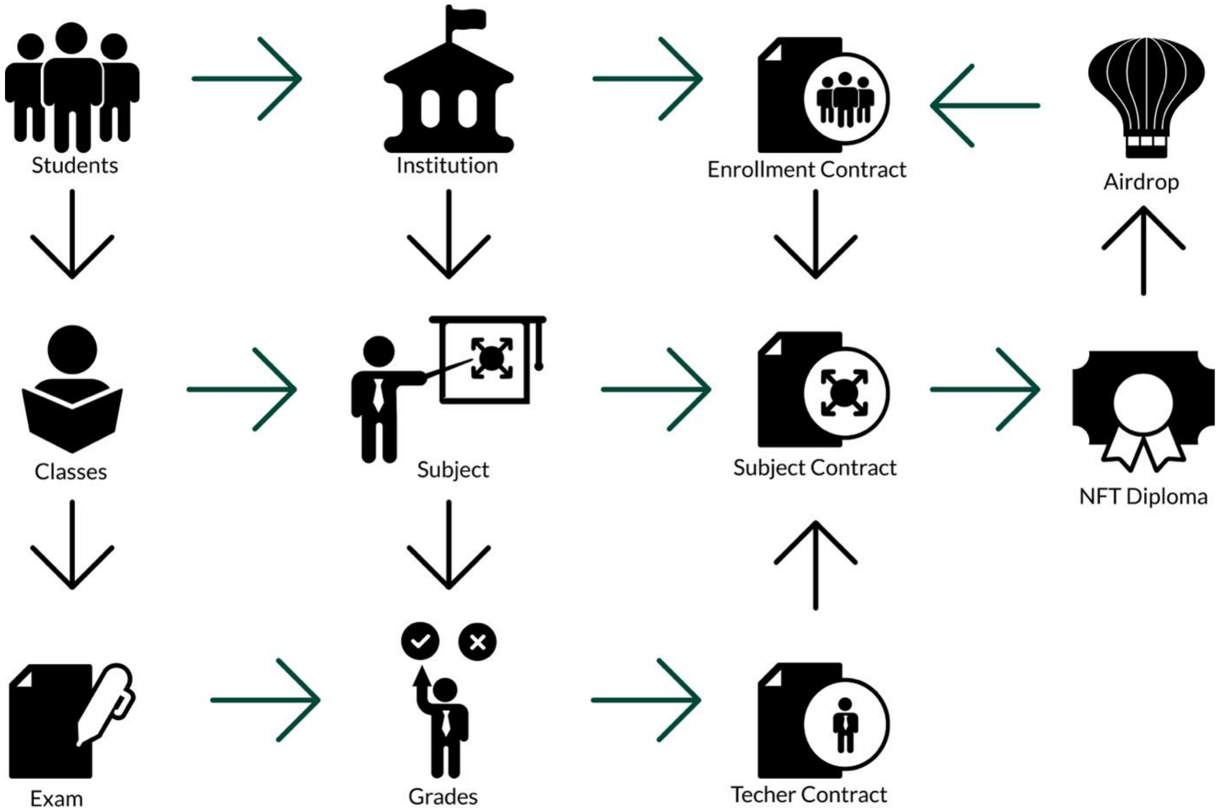

Fig. 3. Process for issuing and NFT Based Diploma

A broader architecture of a diploma system, as depicted in Figure 3 can be extended to the enrollment process and all the steps up to issuance, such as the intermediate ones, i.e., attending classes, taking exams, assigning grades, and calculating the entire credit quotient.

The advantage of such an architecture is that the block can become a management tool for the entire Education supply chain. The Institution or Degree Issuing Authority must portray the smart contract developer role. A first contract can even be used to register students. This contract may reduce the risk of creating degrees without attending classes for some individuals. The business logic behind the creation of diplomas is influenced by evaluating entities, i.e., by teachers. Teachers are registered as collaborators within the institutions, so if the assessment work needs to be recorded on blockchain, they must be enrolled similarly to students. In other contracts, the logic of the evaluation and grading will take place. The student evaluation will be made according to the permissions given by the two contracts, the enrollment and the teacher.

An NFT-type diploma can be issued when certain logic, such as a certain number of credits or threshold, is met in a particular contract. The newly minted diploma will be sent to enrolled students through airdrops. Airdropping occurs when a new NFT ships to a new address without a financial transaction. The transfer will be made to a wallet owned by each individual student. The respective wallet can be a classic one created by each student prior to registration, or it can, in turn, be a Smart contract, abstracting the student's complete interaction with the blockchain.

This architecture solves a common problem, namely proving one's degree. Once issued, the diploma will live on blockchain without requiring the issuing institution to reconfirm it. However, the development continues.

6 The Validation Process

6.1 Privacy and Regulations Considerations

Alongside evaluating blockchain features, the privacy requirements specific to the education sector must be carefully examined. This involves assessing whether certain types of sensitive data, including personally identifiable information (PII) or educational records, necessitate privacy safeguards and should not be exposed globally within a blockchain network. Furthermore, it is essential to consider whether any educational data handled within the blockchain is subject to privacy regulations, such as the Family Educational Rights and Privacy Act (FERPA) or the General Data Protection Regulation (GDPR). The need for selective data exposure to different participants, such as educational institutions, employers, or certification authorities, should also be considered. Should the analysis indicate a significant need for data privacy, selecting a permissioned blockchain framework, such as a private blockchain or frameworks with limited privacy features, may be warranted. This evaluation process assists in identifying the most appropriate frameworks and determining the requisite skills and resources for successful blockchain implementation in the education domain.

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Many of these questions related to data privacy will be resolved through a regulatory framework. A new regulation framework is set to become enforceable from December 30, 2024, the Markets in Crypto-Assets Regulation (MiCA) [10], issued by the EU Commission. MiCA ca's role is to provide a clear direction and a comprehensive overview of the evolving trends in the regulation of crypto-assets. MiCA is an EU directive intended to provide legal certainty for crypto-assets not covered by existing EU legislation. EU directives act as general laws meant to replace national laws. Thus, the law will be uniform in its applicability at the EU level. MiCA can have a similar effect globally as GPDR: to set a trend and provide a way of implementation and re-information for other countries.

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6.2 Security Considerations

All contracts must participate in the exact development mechanism and apply the same best practices before being submitted to the blockchain. Smart contracts are immutable; hence, the upgrade is not possible. Instead, it is possible to deploy a new contract, so all contracts should follow a template by which data and functions are separated [11]. Initial testing is also recommended: it can be done through a local deployment or on a blockchain test, as drawn in Figure 4

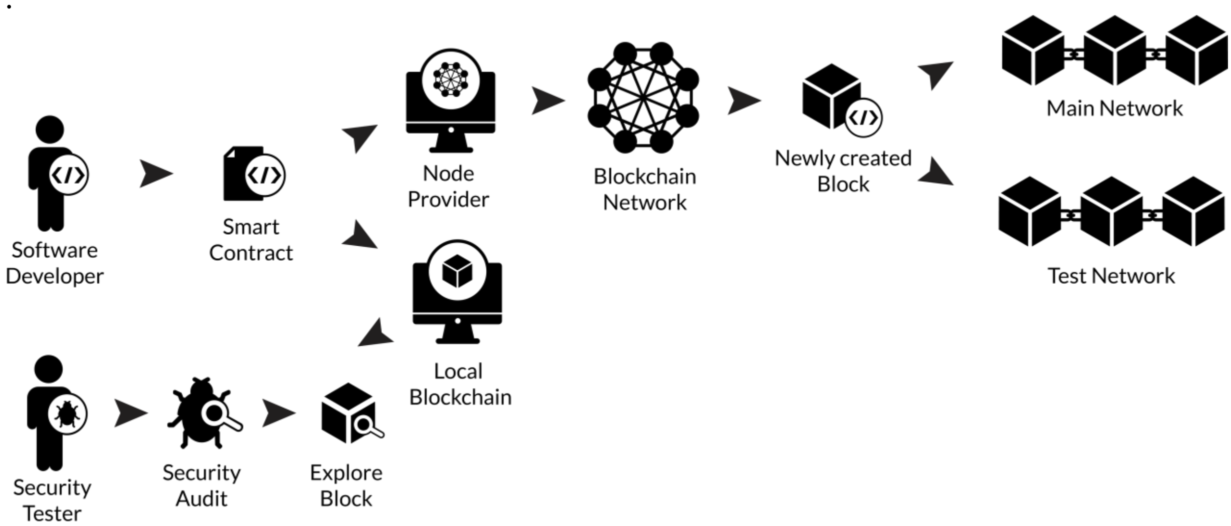

Fig. 4. Testing Smart Contracts on Local Machines

Also, before deploying, it is recommended that audits be created on Smart contracts. Industry best practices say that audits should be performed by entities outside the developing organization. Audits are of critical importance as, within this architecture, data will come from external blockchain sources. The entities that will enter data from the real world, such as notes, will act as oracles. One of the most common security issues is called oracle manipulation.

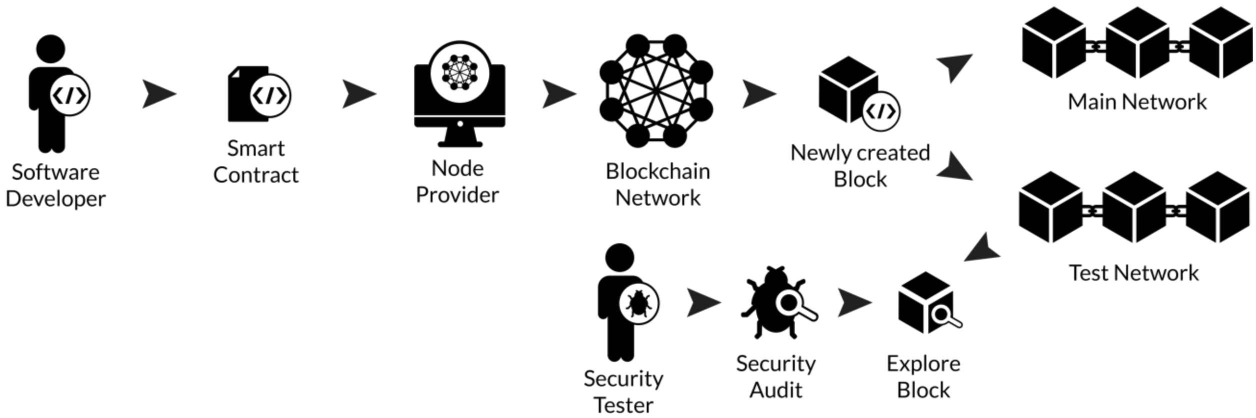

Fig. 5. Testing Smart Contracts on Test Networks

Figure 5 depicts the role and input of a security auditor for security testing smart contracts. In best practices, the auditors should carry out their activity before deploying it to the main chain. [14]

7 Conclusions and Future Work

Innovation is increasingly carrying a digital structure. Blockchain, with its unique potential, could potentially revolutionize the education sector, serving as its operating system.

If any technology is to become mainstream, it must consider not only the technical aspects but also the business factors, such as stakeholders or the added value offered, as well as the ecosystem factor, influenced by competitors, economic crises, and regulation.

When implementing a blockchain solution, one must ask a series of questions: What is the problem/ use case? Does it fit the blockchain characteristics? What are the assets involved? Database? Permissions? Asset creation rights? Transactions?

Nevertheless, blockchain solutions are only as good as their ability to integrate with existing exterior systems and offer concrete solutions with high-value propositions. Implementing blockchain in education can enhance transparency, security, and efficiency in managing academic records. It can simplify verifying credentials, reduce fraud, and streamline administrative processes, ultimately benefiting students, educators, and institutions by building a more trustworthy and accessible system.

Factors such as contract security, data privacy, alignment with regulatory frameworks, and application ease of use will influence the success of solutions. Therefore, it is crucial to foresee how the auditing, testing, and maintenance will be performed. Regular audits must be performed to ensure compliance and identify vulnerabilities, while thorough testing should validate the reliability and functionality of the blockchain applications.

Ongoing research must address emerging issues in order for the system to adapt to evolving educational needs and ensure long-term sustainability and effectiveness.

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