

Research on a Multi-dimensional Student Evaluation Mechanism Driven by Blockchain

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Abstract

The rapid evolution of digital information technologies has exposed critical limitations in traditional academic evaluation systems for students. Persistent challenges—including data inaccuracies, subjective biases in results, and procedural opacity—undermine the reliability and validity of assessments across key dimensions, including evaluation criteria, evaluator diversity, effectiveness measurement, and systemic trustworthiness. Blockchain technology, with its core attributes of immutability, decentralization, and cryptographic security, offers a paradigm-shifting solution uniquely aligned with the functional imperatives of modern educational assessment. This paper proposes the development and implementation of a blockchain-based multi-dimensional student evaluation mechanism. By leveraging distributed ledger technology to record and verify academic achievements, skill development, and behavioral metrics, the system ensures unprecedented data integrity and process transparency. The deep integration of this technological infrastructure with pedagogical workflows enables real-time, tamper-proof documentation of learning trajectories. Such integration effectively resolves longstanding issues of credibility and fairness in student assessment. Consequently, this approach not only enhances educational quality through objective, verifiable performance analytics but also fosters institutional accountability. Ultimately, it catalyzes data-informed pedagogical innovation and makes significant contributions to systemic reforms in higher education teaching methodologies, accreditation standards, and learner-centric educational ecosystems.

Keywords: *Blockchain-based evaluation, Multi-dimensional assessment, Educational reform*

1. Introduction

With the continuous evolution of educational concepts and the rapid advancement of information technology, multidimensional student evaluation has emerged as a significant research direction in educational assessment. The traditional student evaluation system typically bases its assessment on final exam scores. This single evaluation method neglects the diverse abilities and potential students demonstrate during the learning process, such as classroom participation, teamwork, and innovative thinking. At the same time, traditional evaluation methods also have problems, including poor data transparency, intense subjectivity in evaluation results, and low feedback efficiency, which make it challenging to meet the

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needs of modern education for personalized student cultivation and all-around development. In current educational practices, the limitations of student evaluation are prominently manifested in the following aspects. First, the credibility of evaluation results is often questioned. The reason is that traditional evaluation data is easily tampered with and lacks unified standards and guarantees of fairness [1].

To address the issues above, the introduction of blockchain technology [2] offers a brand-new solution for the educational evaluation system. With its decentralized architecture, data immutability, and high transparency, blockchain has demonstrated significant potential for application in education [3]. By storing student evaluation data through a distributed ledger, blockchain technology can effectively prevent data tampering and forgery. This technical feature ensures the security and authenticity of the data, providing educational institutions with an efficient and fair evaluation method.

Under this framework, this study focuses on the following core issues:

1. How can blockchain technology be utilized to achieve transparency and immutability of student evaluation data?
2. How to design and integrate multi-dimensional student evaluation models to comprehensively reflect students' comprehensive abilities?
3. How to build a student evaluation network platform by using blockchain technology?

Through in-depth research on the issues mentioned above, this study aims to propose a comprehensive set of technical solutions and provide practical tools for educational institutions to enhance their student evaluation and feedback systems. Meanwhile, the achievements of this research will also provide theoretical support for the transformation of educational informatization. They will explore additional application scenarios for blockchain technology in education, such as personalized learning path design and cross-institutional academic accreditation. This innovative practice is not only of great significance to the current educational reform but also provides a new direction for future educational technology research.

2. The interaction between blockchain technology and the multi-dimensional student evaluation system

2.1. Application of blockchain technology in the field of education

The application of blockchain technology in education has gradually drawn the attention of the academic community, particularly for addressing issues of data storage, transparency, and credibility. Research shows that blockchain technology offers significant advantages for managing students' academic records, and its immutability ensures the authenticity and security of the data. For example, the Edu-Pro project has developed a reward-and-feedback system using blockchain and smart contracts, thereby enhancing students' learning motivation and participation [4].

2.2. Advantages of applying blockchain technology to multi-dimensional student evaluation

With the support of blockchain technology, the design and application of the multi-dimensional student evaluation model have been further optimized. This not only resolves numerous problems and drawbacks that emerged in traditional educational evaluation but also effectively promotes the fairness, credibility, and efficiency of education, providing new impetus for the development of higher education and enabling the construction of a multi-

dimensional, digital student evaluation system. Figure 1 illustrates the key advantages of applying blockchain technology—such as Ethereum, DApps, smart contracts, and distributed storage—to a multi-dimensional student evaluation system. These features enhance data security, traceability, participation, and efficiency in the assessment process.

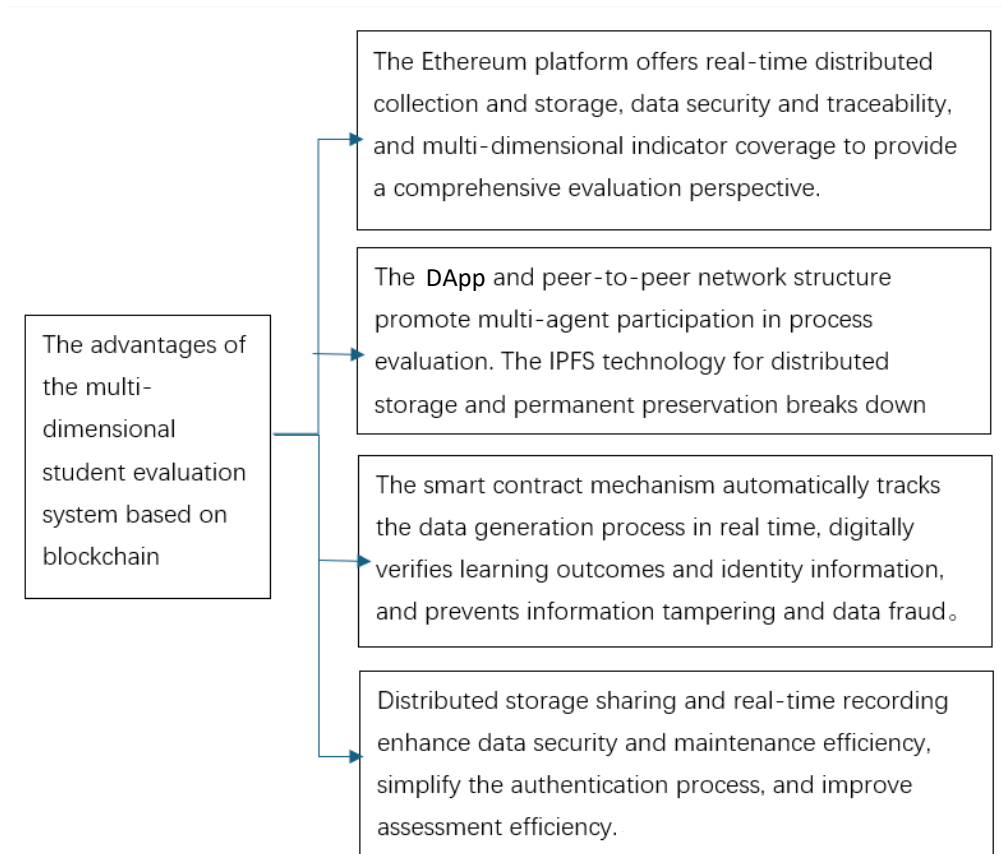


Figure 1. Key advantages of a blockchain-based multi-dimensional student evaluation system

Firstly, blockchain technology, through the Ethereum platform, realizes the real-time distributed collection and storage of higher education evaluation data, meeting the data requirements of diverse evaluation indicators. A comprehensive student evaluation system not only helps students identify problems, address deficiencies, and enhance the quality of learning, but also assists them in forming effective career plans, promoting employment, and meeting the social demand for education. Student evaluation encompasses multiple dimensions, including identity verification, academic performance and subjects, comprehensive quality, internships and practical training, credit certificates, quality assessment, academic records, and follow-up evaluation. It is necessary to rely on scientific methods and technical means to ensure the scientific validity, objectivity, and operability of the review [5]. The smart contract mechanism in Ethereum effectively prevents external interference, and data is traceable and immutable. The evaluation results can be promptly fed back to universities, teachers, and students for improvement. It can also be authorized to share with third-party recruitment enterprises to provide accurate and comprehensive information

about job applicants, facilitating precise matching between people and positions, and enhancing the employment rate.

Secondly, the DApp (Decentralized Application) and peer-to-peer network architecture of blockchain technology can effectively support the development of a multi-agent evaluation system. By achieving process-based evaluation with the simultaneous participation of multiple subjects, blockchain technology has enhanced the fairness, objectivity, and comprehensiveness of student evaluation [6]. Traditional student evaluation has several problems, including restricted evaluation subjects and authorities, as well as opaque student information, which makes it difficult for students to use evaluation information for self-planning and self-improvement. Additionally, third-party employers struggle to obtain comprehensive talent information, leading to a mismatch between supply and demand in the talent market. In the decentralized blockchain system, IPFS technology enables the distributed storage and permanent preservation of data information through a distributed file system. Meanwhile, the data on the blockchain is confirmed by each node through a consensus mechanism to ensure its maintenance and updates. This enables the development of a network system for multi-node information generation, collection, integration, and processing, thereby breaking down information silos, providing more comprehensive and transparent evaluation information for students and employers, and promoting the sound development of education and employment.

Then, the smart contract mechanism of blockchain technology can effectively guarantee the authenticity and security of educational evaluation data, thereby enhancing the credibility of college students' evaluation information. The traditional student evaluation system in higher education faces trust crises, including information tampering and the dissemination of false information, which hinder and restrict the sound operation of the talent market. The blockchain platform automatically tracks the data-generating process in real time via smart contracts. It enables hash value verification during data transmission to ensure that the data is uploaded to the chain after being confirmed by each node and cannot be tampered with after being uploaded to IPFS, thereby achieving data authenticity, integrity, and traceability, and eliminating external interference. In practical applications, students' learning achievements and identity information can also be verified digitally, effectively preventing tampering and data fraud [7].

Finally, the distributed storage sharing and real-time recording capabilities of blockchain technology can significantly enhance evaluation efficiency and facilitate the efficient implementation of evaluation-driven improvement. The traditional higher education evaluation system often faces problems such as complex management processes and slow information transmission. However, blockchain utilizes a Peer-to-Peer (P2P) network for data transmission and sharing, eliminating the need for a central server. After the terminal uploads data, all accounting nodes will synchronize and back up their data. This distributed storage method effectively prevents data loss or corruption caused by the failure of a single node, thereby enhancing the security and fault tolerance of the data.

Meanwhile, the automated management of smart contracts reduces human operational errors and time costs. In a decentralized network, each node has equal rights and obligations, and system operation and maintenance are carried out collectively, ensuring data security and improving maintenance efficiency. For example, third-party recruitment units can browse credit reports generated by multiple parties along the chain, verify the authenticity and credibility of students' information using blockchain's security features, simplify the certification process, and improve assessment efficiency.

3. Design of a multi-dimensional student evaluation system based on blockchain technology

This paper takes the comprehensive ability evaluation of students as an example to explore the digital construction scheme of the educational evaluation system platform based on blockchain technology. In the system function design, the data collection logic and module architecture of blockchain in the financial system and the government affairs system were referenced, which demonstrates high practicality and technical feasibility. This system is mainly divided into three parts: data framework, data collection and analysis, and a system network support platform, as shown in Figure 2.

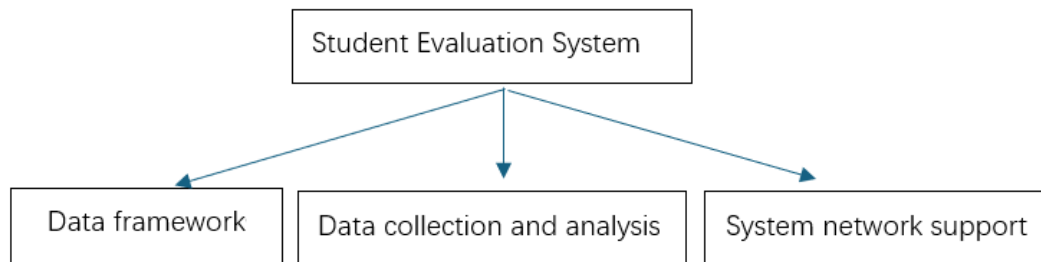


Figure 2. Multi-dimensional student evaluation system

3.1. Build a multi-dimensional guided data flow architecture based on blockchain technology

Blockchain technology enables the synchronous sharing of multidimensional data on the chain. In comprehensive ability evaluation, professional ability assessment is the core link, involving students' mastery of professional knowledge and the improvement of related business qualities. From the perspective of student cultivation, the assessment process is student-centered, outcome-oriented, and focuses on the entire learning process. It completes comprehensive assessments and evaluations through testing and feedback mechanisms. The model's testing module is responsible for collecting relevant student parameters, including knowledge mastery, learning progress, and improvements in quality and ability. It converts abstract learning behaviors into digital credit data and forms a comprehensive learning process database. Ultimately, the evaluation results are transformed into students' learning credit archives, stored, and shared on the chain, and displayed through information windows on the front end. In the student professional ability assessment module based on blockchain technology, it first records the professional teaching activities and achievements of students (as a representation of professional ability); then analyzes the correlation between the two and calculates the influence coefficient; finally, it examines the similarity between students through these two parameters, providing a reference direction for differentiated and personalized development for students of the same major.

3.2. Build a data collection and data analysis module based on blockchain technology

When building an education evaluation system based on blockchain technology, data collection is the foundation of the entire system. Its design fully considers the role of evaluation information throughout the talent cultivation process, emphasizing the diversification of evaluation subjects, the comprehensiveness, and the process-oriented nature

of evaluation links. Data collection encompasses multiple evaluation endpoints, including theoretical learning platforms, internship and practice platforms, professional competition platforms, internship and employment platforms, and collaborative education platforms, ensuring that education evaluation spans the entire talent cultivation process. By leveraging the decentralized, distributed collection, full-process recording, timestamping, and immutability features of blockchain technology, the system introduces multiple subjects (such as students, teachers, experimental systems, off-campus mentors, competition organizing units, and employment and entrepreneurship units, etc.) to conduct all-round and objective evaluations of students at various nodes and periods. Through data mining algorithms, the collected evaluation data is integrated to form a comprehensive student information archive database, providing detailed data support for the comprehensive ability assessment of college students. This multi-party collaborative evaluation mechanism not only implements the "end-to-start" talent cultivation model but also aligns talent cultivation plans with employers' job competency requirements, thereby meeting industry standards and social development needs.

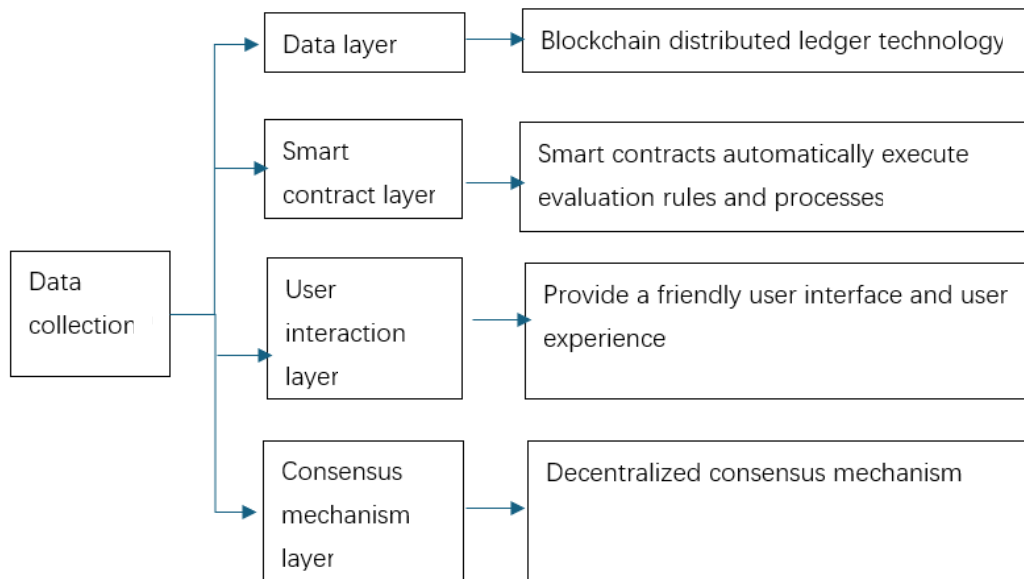


Figure 3. Data acquisition module

Figure 3 presents the layered architecture of the data acquisition module, highlighting its integration with blockchain technology. It includes the data layer, smart contract layer, user interaction layer, and consensus mechanism layer, each playing a distinct role in ensuring secure, automated, user-friendly, and decentralized data collection and evaluation. At the data layer, blockchain's distributed ledger technology ensures data security and immutability. Each data block contains a timestamp and a hash value, linked via a hash chain to ensure the integrity and traceability of the data. The data collection module encompasses multiple links, ensuring that educational evaluation is integrated throughout the entire talent cultivation process. Multiple parties evaluate students comprehensively and objectively at each node and period. Data is collected in a distributed manner and recorded on the blockchain in real-time, forming a comprehensive database of student information. At the smart contract layer, smart contracts, as the core of the system's automation, can automatically execute preset evaluation rules and processes, reducing manual intervention and improving the efficiency and fairness

of the evaluation. Smart contracts can automatically record students' performance data for each educational link, ensuring real-time accuracy, while managing data-sharing permissions to allow only authorized nodes to access and use the data, making the evaluation process more transparent. At the user interaction layer, a user-friendly interface enables various user roles, including students, teachers, school management, and third-party evaluation institutions, to conveniently access and utilize the system. Students can view their evaluation results, understand their learning situation, and identify areas for improvement; teachers can access students' learning data and adjust their teaching methods; school management can analyze overall evaluation data and optimize the allocation of teaching resources; third-party evaluation institutions can obtain authorized student data for talent assessment. The design of the user interaction layer focuses on user experience, providing convenient operation processes and real-time feedback mechanisms to ensure that users can use the system efficiently. At the consensus mechanism layer, the decentralized consensus mechanism is the fundamental guarantee of the system. Through the consensus mechanism, multiple nodes in the system can reach an agreement, ensuring the authenticity and reliability of the data. Under the consortium chain architecture, new nodes must obtain authorization to participate in the chain, with limited, controllable permissions. All nodes on the chain are elected publicly through the consensus mechanism, and the elected nodes are responsible for maintaining the ledger. Only newly authorized nodes can join the network. This decentralized consensus mechanism not only enhances the system's security and reliability but also promotes cooperation among participants. Through the consensus mechanism, all evaluation data is verified and confirmed by multiple nodes, ensuring its authenticity and immutability.

By combining data collection with the multi-layer architecture of blockchain, the educational evaluation system can achieve secure data storage, automated processing, convenient interaction, and reliable consensus. This architecture not only meets the scientific and objective requirements of educational evaluation but also promotes alignment between talent cultivation plans and employers' job competency requirements, thereby meeting industry standards and social development needs. With the help of blockchain technology, the educational evaluation system can provide an efficient, transparent, and reliable evaluation platform for students, teachers, school management, and third-party evaluation institutions, thereby promoting educational digital transformation [8].

In the data analysis process, based on the system platform's development requirements, a Web application model with front-end and back-end separation is constructed. HTML is used to write the front-end interface of the development platform, and CSS, with its cascading web layout, can provide a comfortable user experience. In the development process of the back-end Web program, given the subsequent requirements for data migration and cross-platform support on the chain nodes, Java, which is simple and easy to use, is more applicable [7]. Based on the above design, the system can meet the requirements of easy access, cross-platform, and high security. In terms of analysis algorithms, based on the training plans of colleges and universities and the design requirements of the evaluation system, data mining algorithms are used to identify the relationship between students' comprehensive abilities and learning practices, thereby establishing the data logic flow of the evaluation system [9]. Firstly, to obtain the influence weights of teaching activities on various comprehensive abilities, the Apriori data mining algorithm can be used to analyze the correlation coefficients between the two, thereby determining the relationship between teaching design and ability cultivation. Secondly, the weights obtained above and the students' grade data are used as parameters, and the Sim Rank algorithm is employed to calculate the similarity between students in the same major. Finally, the similarity mentioned above is used as the Euclidean

distance in the cluster analysis, and the K-means algorithm is used to cluster student groups. In terms of functional design, the learning credit management model is introduced into data analysis, and students' learning data is integrated into learning bills. After integrating the learning credit, it is uploaded to the blockchain [10]. The parent block hash value set on the block can effectively enhance the security of the learning credit report, forming a decentralized, immutable learning credit chain that facilitates efficient, convenient verification of employers' file information by students. As an external data source for this system design, the blockchain requires installing a wallet plugin to interact with the system. Therefore, it is also necessary to build a blockchain network to support the system's development.

3.3. Building a student evaluation network architecture based on blockchain technology

Based on current teaching practices, this paper proposes adopting a blockchain-based "off-chain storage + on-chain sharing" model to build a unified national, multidimensional student comprehensive evaluation data platform. By leveraging the technical advantages of the Nebulas chain and using the "consortium chain + side chain" technology, it promotes the diversification of smart contract encapsulation, eliminates the fragmented state of educational evaluation data, realizes the open sharing of educational data, and builds an open and transparent educational data ecosystem, thereby enhancing the scientificity and objectivity of student evaluation [11].

A consortium chain is a "partially" decentralized network in which new nodes must obtain authorization to participate, with limited, controllable permissions. All nodes on the chain are elected publicly through the consensus mechanism, and the elected nodes are responsible for maintaining the ledger. Only the newly authorized nodes can join the network. This permission management approach can better promote cooperation among different participants on the chain. In the student evaluation system consortium chain, the regulatory authorities act as key nodes and authorize and supervise participants, both within and outside the school, as administrators. Other nodes on the chain must be approved by the "administrator" to read, write, and use data. Different evaluation subjects and types enjoy different operation permissions. Other user roles are assigned varying data sharing permissions, and the platform can configure system modules to accommodate the needs of regulatory authorities, school-level management, third-party evaluators, teachers, students, and others, as required. After the school uploads educational activity data to the chain, each module can request data queries and access based on authorized permissions.

Additionally, evaluation data can be simultaneously stored on the chain. Based on the multi-dimensional sharing advantages of the consortium chain, the school can create an "in-school consortium chain" as a side chain of the overall evaluation system. The school acts as the platform administrator to edit, authorize, supervise, and use the data, and all nodes jointly participate in reading, writing, and maintaining the data. Relay technology enables cross-chain data sharing, enabling efficient data interaction between different chains.

Smart contracts play a crucial role in the architecture of the student evaluation network. They can automatically record students' performance data at various educational stages, ensuring real-time accuracy, and verify uploaded data through verification functions to ensure authenticity and integrity. Smart contracts can also automatically assign evaluation tasks to different evaluation subjects based on preset rules, calculate evaluation results automatically, and generate comprehensive ability evaluation reports for students. At the same time, smart contracts can manage data-sharing permissions, ensuring that only authorized nodes can

access and use the data, and can protect students' privacy information through encryption [12]. Additionally, smart contracts can provide real-time feedback on evaluation results to students, teachers, and school management, helping students understand their learning situation, teachers adjust their teaching methods, and schools optimize their teaching management. They can also automatically trigger improvement tasks based on evaluation results, thereby promoting continuous improvement in educational quality [13].

The Nebulas chain has stronger compatibility and faster search capabilities, making it suitable for the development and application of the evaluation system consortium chain. Linking data through the Nebulas chain and enabling interaction with open-source chains can effectively enhance the system's performance and efficiency. The automated management of smart contracts reduces errors and time costs associated with manual operations, while ensuring the security and immutability of data, thereby improving the overall performance and reliability of the system. Through this architecture, the student evaluation system not only meets the requirements of scientificity and objectivity but also promotes cooperation among different participants, driving the development of educational digital transformation.

4. Conclusion

In conclusion, blockchain technology offers a novel solution for managing and evaluating student data, while the multidimensional student evaluation model provides a theoretical framework for comprehensively assessing students' abilities. By leveraging the characteristics of blockchain technology, such as full-process recording, storage, and sharing, immutability, and decentralization, a multi-dimensional student evaluation system platform is designed. Through flexible and diverse application models such as decentralized authentication and intelligent multi-party recommendation, it achieves precise evaluation while ensuring the authority and traceability of information data, reducing educational information asymmetry, and effectively establishing a multi-party trust mechanism. However, the combination of the two still needs to address the challenges of technical complexity and practical application.

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