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Ethical Regulation of Blockchain Technology and Applications in Higher Education[*]

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Abstract: *With the in-depth application of blockchain technology in the field of education, higher education institutions and practitioners must deeply examine their ethical risks and build the corresponding regulatory framework. On the basis of combining the development status and educational application scene of blockchain technology, this paper analyzes the main ethical challenges faced by blockchain education applications from the dimensions of privacy protection, educational equity, intellectual property rights, educational governance, and so on. In drawing lessons from the principles of educational technology ethics and data protection norms, this paper follows the education-oriented and student-centered concepts and proposes to build the ethical regulatory framework for the educational application of blockchain education from the aspects of ethical awareness cultivation, code of conduct construction, and multi-party participation in governance, with a view to safeguarding the healthy development of higher education enabled by blockchain technology.*

Keywords: *Blockchain; Higher Education; Educational Ethics; Privacy Protection; Institutional Regulation*

I. Introduction

Blockchain technology, with its typical characteristics of decentralization, immutability, and traceability, is driving a new wave of changes in the education sector. Higher education, as the highest level of talent cultivation, should take the lead in embracing blockchain innovation to reshape the talent training model and improve the quality of educational services. However, it has also raised many ethical issues and challenges that need to be addressed urgently. Faced with the ethical dilemmas brought about by the integrated development of blockchain technology and higher education, we should neither be confined to technological enthusiasm and ignore its negative impact, nor deny its innovative value. At present, China's higher education is at a critical stage of connotative development and digital transformation, and there is an urgent need to systematically examine the ethical risks of blockchain technology application based on the concept of educational fairness and justice, clarify the path and strategy of blockchain education ethics regulation in inheriting tradition, grasping reality and leading the future, and then promote the formation of an ethical norm system conducive to blockchain innovation and in line with the law of higher education development, so as to provide solid ethical support for the high-quality development of higher education in the new era.

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II. Blockchain Technology Development and Its Application in Higher Education

Blockchain technology is a distributed ledger technology characterized by decentralization, immutability, and traceability. Its core significance lies in realizing data sharing, verification, and storage among nodes through cryptography principles and consensus mechanisms without the premise of centralized trust endorsement, thus providing a new paradigm for building a trusted value transfer network.

(1) Distributed Ledger Technology

The distributed ledger is the essential feature of blockchain. Unlike traditional centralized ledgers, blockchain adopts a distributed ledger structure, where ledger data is shared and synchronized among all nodes, and each node can obtain a complete data backup, thus effectively improving system availability and data immutability. For example, Alibaba has used distributed ledger technology to build the world's largest blockchain cross-border remittance network, realizing 170,000 cross-border remittances totaling $4.13 billion, with an average arrival time of less than 3 seconds[1].

(2) Consensus Mechanism

The consensus mechanism is one of the key technologies of blockchain. Through specific algorithms, the states of various nodes in a distributed system are synchronized, thus realizing the consistency and tamper-proofing of distributed ledgers in the absence of a central trusted party. For example, the Monetary Authority of Singapore has cooperated with several banks to successfully pilot "atomic" cross-currency transactions in wholesale payments based on the blockchain consensus mechanism, with funds directly remitted from Singapore to Canada and Australia without going through the US dollar [2].

(3) Smart Contract

The smart contract is an important application form of blockchain. It is essentially a self-executing code deployed on the blockchain. By writing contract terms into the blockchain in the form of programming language in advance, once the conditions are triggered, it can be automatically executed without human intervention, effectively reducing transaction costs and improving contract execution efficiency. For example, China's first blockchain electronic bill platform went online on JD Technology's "Xilian", realizing automatic bill issuance, endorsement, and redemption through smart contracts, with a cumulative transaction volume exceeding 50 billion [3].

In summary, blockchain has gradually evolved from a simple underlying technology for digital currency to a brand-new mechanism for building trust and transferring value. Through core technologies such as distributed ledgers, consensus mechanisms, and smart contracts, it provides new ideas for solving the pain points of low efficiency and opacity in centralized systems. In the future, with the deep integration of blockchain with emerging technologies such as cloud computing, big data, and artificial intelligence, it is expected to achieve greater breakthroughs in areas such as digital government, smart cities, and supply chain management, injecting new momentum into the digital transformation of the economy and society.

III. Typical Application Scenarios of Blockchain in Higher Education

(1) Academic Degree and Certificate Authentication

The traditional process of academic degree and certificate authentication is cumbersome and inefficient, and paper certificates are easy to forge and difficult to verify. Blockchain technology provides a new solution to this pain point. By putting degree certificate information on the chain, it realizes permanent storage, credible verification, and global circulation of certificates, effectively improving the efficiency of certificate management and combating academic fraud. For example, MIT has used blockchain to issue digital degree certificates to 2,500 graduates, with certificate information hashed and put on the chain to ensure authenticity and credibility, and supports students' autonomous management and sharing [4].

(2) Credit Transfer and Mutual Recognition

Inter-university credit transfer and mutual recognition an important measures to improve the quality of talent cultivation and promote the sharing of educational resources. However, due to factors such as inconsistent university standards and complex procedures, the efficiency of credit mutual recognition is low. Blockchain provides an efficient path for credit mutual recognition. On the one hand, by putting course credits on the chain, it realizes transparent credit information storage, and credible verification, and prevents credit fraud; on the other hand, it uses smart contracts to write credit mutual recognition rules into the blockchain, realizing automatic credit conversion and real-time settlement, greatly improving the efficiency of credit mutual recognition. For example, the University of California, Berkeley has put student course credit information on the chain, making it convenient for students to transfer credits between different colleges and universities, and improving educational mobility [5].

(3) Intellectual Property Protection

Universities are important institutions for knowledge production, but paper plagiarism, patent infringement, and other intellectual property infringement behaviors are not uncommon, damaging the innovation incentives of universities. Blockchain provides a powerful tool for strengthening intellectual property protection in universities. By hashing and chaining intellectual property information such as papers and patents, it uses blockchain's timestamp mechanism to realize credible confirmation of intellectual property rights, and supports rights transfer and dividend distribution, stimulating the innovation motivation of university faculty and students. For example, the National Academy of Development and Strategy at Renmin University of China initiated a university intellectual property alliance chain, joining hands with multiple universities to explore innovative paths for blockchain to help protect intellectual property [6].

(4) Educational Data Management

Universities gather a large amount of data on faculty and students, but data value mining is insufficient due to data silos, privacy leaks, and other issues. Blockchain provides a new solution to break the educational data dilemma. By putting educational data on the chain, it realizes multi-party data sharing and collaborative analysis while ensuring data privacy and security, improves data utilization efficiency, and empowers teaching management decisions. For example, the National University of Singapore has used a consortium chain to build a campus data governance framework, promoting data open sharing on the basis of ensuring data sovereignty through fine-grained data access control and secure multi-party computing [7].

On the one hand, blockchain is expected to break the pain points and bottlenecks that have long constrained the development of higher education, such as information silos, data barriers, and fragmented learning processes. On the other hand, the integration and development of blockchain and higher education is still in its infancy and exploration stage and still faces many challenges. There is an urgent need for collaborative efforts from industry, academia, research institutions, and the government to accelerate the penetration of blockchain technology achievements into education and teaching scenarios, improve top-level design and standard specifications, create a good institutional environment, and cultivate an innovative.

IV. Ethical Review of Blockchain Technology Applications in Education

While blockchain applications in education bring opportunities, they also raise numerous ethical issues and challenges. This paper intends to conduct an ethical review of blockchain technology applications in education from four dimensions: privacy protection and data security, educational equity and equal opportunity, intellectual property protection and open access, and educational governance autonomy and data sovereignty.

(1) Privacy Protection and Data Security

Firstly, although blockchain has certain privacy protection mechanisms, there are still risks of data privacy leakage and abuse. For example, research from the University of California, Berkeley found that blockchain education application platforms have issues such as excessive collection and unauthorized sharing of students' personal information [8]. Secondly, the shared ledger mechanism of blockchain makes it difficult for students to achieve personal information autonomy. For instance, scholars from the Open University in the UK pointed out that the immutable nature of blockchain educational records may infringe on the "right to be forgotten" and harm students' information self-determination rights [9]. Furthermore, blockchain data security faces dual challenges of technology and management. For example, the Privacy Protection Project Group of the National University of Singapore demonstrated that there is still a need to balance between protecting privacy and improving efficiency [10].

(2) Educational Equity and Equal Opportunity

Firstly, blockchain education applications may exacerbate the digital divide. For example, a UNESCO report pointed out that there are multiple thresholds for accessing blockchain technology, such as devices, networks, and skills, which may widen the digital divide in education [11]. Secondly, the popularization of blockchain education faces the problem of the digital divide. For instance, the World Economic Forum called for attention to the issue of digital inequality in blockchain education applications, and narrowing the digital divide is key to achieving educational equity [12]. Moreover, algorithmic bias in blockchain education applications may affect the fairness of educational evaluation. For example, research from University College London revealed gender and racial biases in blockchain education application algorithms, which may discriminate against disadvantaged groups [13].

(3) Intellectual Property Protection and Open Access

Firstly, confirming intellectual property rights on blockchain faces many technical and legal difficulties. For example, Stanford University scholars proposed that the distributed storage of blockchain poses challenges to confirming intellectual property rights [14]. Secondly, the encryption mechanism of blockchain hinders the open sharing of educational resources. For instance, scholars from MIT OpenCourseWare believe that the encryption feature of blockchain is contrary

to the concept of open educational resources [15]. Furthermore, the incentive mechanism of blockchain impacts the traditional paid knowledge model. For example, the head of the Oxford University Press blockchain project pointed out that the blockchain incentive model may weaken the discourse power of traditional academic publishers and impact the traditional paid reading model [16].

(4) Educational Governance Autonomy and Data Sovereignty

Firstly, blockchain threatens individual autonomy over educational data. For example, research from the University of British Columbia, Canada revealed that the immutable nature of blockchain may deprive students of control over their personal educational data [17]. Secondly, the cross-border transmission of educational data on blockchain faces legal jurisdiction dilemmas. For instance, the EU Blockchain Observatory pointed out that there is a potential conflict between GDPR and the concept of blockchain, and cross-border transmission of blockchain educational data urgently needs institutional innovation [18]. Moreover, blockchain promotes the commercial development of educational data, triggering ethical controversies. For example, scholars from the Berkman Center at Harvard University called for attention to the ethical boundaries of educational data commercial development activities driven by blockchain [19].

In summary, while blockchain technology brings many opportunities for educational change, the ethical issues in educational applications cannot be ignored. Areas such as privacy protection, educational equity, intellectual property, and data governance face value dilemmas, urgently requiring systematic responses at both the technological development and institutional design levels. In the future, blockchain education applications need the joint efforts of industry, academia, research, and government to consider ethical value demands while giving play to technological efficiency. Adhering to the principles of people-centricity, security and controllability, inclusiveness and prudence, and openness and sharing, we should strive to achieve a dialectical unity of blockchain innovation vitality and educational fairness and justice, empowering high-quality educational development with new technologies.

V. Ethical Regulation Paths for Blockchain Education Applications

Blockchain technology harbors tremendous potential to transform education, but it also poses new challenges to traditional educational values. In the process of blockchain education applications, we must base ourselves on the inherent laws and ethical requirements of education and prudently advance blockchain innovation within the framework of educational equity and justice.

(1) Improving Laws and Regulations

Firstly, it is necessary to improve the legal system for data protection and formulate special blockchain data protection laws to clarify the boundaries of educational data collection, storage, use, and sharing. For example, the European Union's Data Governance Act provides a useful reference for blockchain education data governance [20]. Secondly, the legal status of smart contracts needs to be clarified, their legal attributes need to be sorted out, they need to be given contractual effect, and the formation, performance, and liability for breach of smart contracts in blockchain education applications need to be standardized. For example, the U.S. state of Arizona has legislated to confirm the legal validity of smart contracts [21]. Thirdly, in response to intellectual property issues in blockchain education applications, relevant laws and regulations need to be improved to balance incentivizing innovation and promoting sharing. For example, China has released a white paper on blockchain intellectual property protection, proposing suggestions for improving the system [22].

(2) Strengthening Key Technology Innovation

Firstly, privacy protection key technologies need to be strengthened, and cutting-edge technology research and development such as blockchain privacy computing and federated learning need to be deepened to enhance privacy protection and data security. For example, MIT has proposed a new blockchain privacy protection solution based on trusted hardware [23]. Secondly, consensus mechanisms need to be optimized to improve performance, consensus algorithms need to be improved, and the transaction performance and scalability of blockchain systems need to be enhanced. For example, the National University of Singapore has designed a new efficient consensus protocol that effectively improves the performance of blockchain systems [24]. Thirdly, the bottleneck of cross-chain operation technology needs to be broken through, cross-chain interoperability technology innovation needs to be strengthened, and the interconnection of different blockchain education application platforms needs to be realized. For example, the Open University of the United Kingdom has proposed a secure and efficient cross-chain technology solution to support blockchain education data sharing [25].

(3) Optimizing Business Application Processes

Firstly, blockchain education applications should adhere to the principle of minimum sufficiency and reduce excessive collection of student privacy data. For example, the University of British Columbia in Canada fully practiced the principle of minimum sufficiency in designing its blockchain application for graduate degree certificates, which was widely recognized by students [26]. Secondly, blockchain education applications should give students control over their personal data, allowing them to independently manage the sharing objects and permissions of their data. For example, Stanford University has launched a blockchain education data wallet that allows students to set personal data access rules [27]. Thirdly, blockchain education applications should embed ethical review into business processes and continuously assess potential ethical risks. For example, the blockchain course credit management system developed by Harvard University has a built-in ethical assessment module to achieve early discovery and early handling of ethical issues [28].

(4) Strengthening Education and Training Guidance

Firstly, blockchain basic knowledge should be popularized among teachers and students to help them correctly understand the opportunities and challenges of blockchain education applications. For example, the University of Oxford launched the world's first online course on blockchain education ethics, which is open to learners worldwide for free [29]. Secondly, professional ethics education for practitioners of blockchain education applications needs to be strengthened to improve their risk prevention and ethical responsibility awareness. For example, Nanyang Technological University in Singapore has launched a series of professional conduct training for blockchain education project developers [30]. Thirdly, communication and dialogue among various stakeholders in blockchain education applications need to be strengthened to build ethical consensus in an open and inclusive manner. For example, UNESCO has released blockchain education ethics guidelines, calling on the international community to strengthen collaboration and build consensus [31].

(5) Establishing a Pluralistic Collaborative Governance Mechanism

Firstly, under the guidance of the competent government departments, a cross-sector and interdisciplinary blockchain education ethics committee should be established to be responsible for decision-making and supervision of major ethical issues. For example, the UK has established a National Blockchain Education Standards Committee to

coordinate the development of blockchain education standards and norms [32]. Secondly, the independent advantages of third-party professional institutions in blockchain education application assessment, certification, and arbitration should be brought into play. For example, the American Blockchain Education Alliance has released the first national blockchain education application security assessment standard [33]. Thirdly, schools, enterprises, social organizations, and others should be encouraged to actively participate in blockchain education governance to form a pluralistic joint force. For example, 10 universities and enterprises in Canada jointly launched the Blockchain Education Governance Alliance to build a collaborative platform for industry, academia, research, and application [34].

In summary, the healthy and orderly development of blockchain education applications is inseparable from comprehensive and thorough ethical regulation. By systematically deploying ethical regulation paths and making systematic efforts in the dimensions of law, technology, process, education, governance, and other aspects to prevent and defuse potential ethical risks in a multi-pronged manner, we will surely promote the formation of a standardized, orderly, open, and inclusive blockchain education innovation ecosystem, and then solidly advance education modernization and digital transformation to better serve the fundamental task of fostering virtue through education.

VI. Conclusion

The future development of blockchain education applications relies on society forging ahead in consensus. We must embrace the blockchain technology revolution with an open mind, but also treat blockchain education innovation with a prudent attitude. By making collaborative efforts to improving laws, breaking through technologies, optimizing processes, popularizing education, innovating governance, and other dimensions, we will surely be able to walk steadily and solidly on the path of blockchain education innovation. Facing the future, blockchain education applications must adhere to a people-oriented approach, respect the laws of education, grasp the ethical bottom line, gather the joint efforts of all parties, and strive to explore a path that conforms to educational equity and promotes educational development.

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