

Article

Research on the Construction of a Lifelong Learning Portfolio for Early Childhood Physical Education Teachers Based on Blockchain Traceability Technology

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Abstract: This study aims to develop a lifelong learning portfolio system for early childhood physical education teachers based on blockchain traceability technology. Currently, China's early childhood physical education teaching workforce faces significant challenges, such as insufficient professional competence and highly fragmented continuing education systems. Furthermore, traditional paper-based or centralized electronic portfolios exhibit substantial limitations regarding data authenticity, completeness, accessibility, and overall teacher autonomy. By analyzing the broader policy context and the practical challenges of lifelong learning for early childhood physical education teachers, and by thoroughly examining the core shortcomings of existing portfolio management models, this study proposes a robust, multi-layered system framework. This innovative architecture comprises distinct data layers, network layers, consensus layers, contract layers, and application layers. Additionally, it designs key operational processes, including secure identity authentication, continuous learning process documentation, immutable achievement certification, and authorized access queries. The study demonstrates that this decentralized system can successfully establish credible, comprehensive, self-managed, and shared lifelong learning portfolios for educators. Consequently, it not only enhances their continuous professional development but also provides highly reliable data support for employers, training institutions, and educational authorities. Ultimately, this technological integration significantly advances the professionalization and standardization of the early childhood physical education workforce. Finally, the report analyzes potential technical and non-technical challenges in system implementation and outlines future development prospects for blockchain in educational management.

Keywords: blockchain; lifelong learning; physical education; professional development; data traceability; smart contracts

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1. Introduction

With the deepening implementation of the "Healthy China" strategy and the widespread adoption of the concept of national fitness, the foundational role of sports in the comprehensive development of young children has gained increasing recognition. The early childhood period is a critical phase for the development of children's physical fitness, exercise habits, and healthy personality traits [1]. High-quality physical education for young children holds profound strategic significance for enhancing the overall quality of the nation. Currently, the professional development of physical education teachers for young children in China faces severe challenges over the long term. The primary issues include a severe shortage and structural imbalance in teaching staff. Survey data indicate that the vast majority of kindergartens in China do not have full-time physical education teachers; physical activities are often conducted by classroom teachers. Approximately 95% of kindergartens nationwide lack dedicated physical education teachers, and 95% of

existing physical education teachers lack professional background, systematic knowledge of physical education theory, specialized skills in providing exercise guidance, or the ability to design physical activities tailored to the physical and mental development characteristics of young children. As a result, the scientific rigor, systematic approach, and engaging nature of physical education curricula for young children are significantly compromised.

In response to the heightened demands placed on education in the new era, lifelong learning and continuous professional development for teachers have become a central tenet of national education policy. The "Professional Standards for Kindergarten Teachers (Trial)" issued in 2012 explicitly identifies "lifelong learning" as one of three fundamental principles, emphasizing its role as a prerequisite and enduring driving force for teacher professional growth. The standards require teachers to "possess awareness and capacity for lifelong learning and continuous development," consistently "study advanced theories of early childhood education and familiarize themselves with domestic and international experiences and practices in preschool education development," while continuously "optimizing their knowledge structure and enhancing cultural literacy." For early childhood physical education teachers, who are subject to particularly high professional standards, lifelong learning is essential for keeping pace with advancements in sports science, updating teaching philosophies, adopting emerging instructional methods, and addressing evolving child development needs.

2. Problem Statement

Within the policy framework of lifelong learning, effectively documenting, certifying, managing, and applying the professional development journey of early childhood physical education teachers to establish a credible lifelong learning portfolio has become a critical challenge. However, current portfolio management approaches suffer from several entrenched flaws that significantly hinder the implementation of lifelong learning principles. Currently, teacher learning portfolios primarily exist in two forms: traditional paper-based records and centralized electronic information systems. Both models have revealed four fundamental issues in practice:

(1) Susceptible to loss and difficult to trace: Paper-based materials are highly prone to loss or damage due to improper storage, and are challenging to systematically retrieve or trace. Centralized systems, however, carry the risk of single-point failures; once a server fails or the system ceases operation, all data may be permanently lost, rendering historical records unverifiable [2].

(2) Lack of cross-institutional recognition: Learning records and achievements obtained by teachers from different regions, training institutions, or kindergartens often fail to gain recognition in new workplaces or evaluation systems due to the absence of unified data standards and mutual trust mechanisms. This "data silo" phenomenon significantly diminishes the value of teachers' learning outcomes and hinders the free mobility of talent as well as the fairness of evaluation systems [2].

(3) Learning outcomes are susceptible to unauthorized alterations: Paper certificates lack robust anti-counterfeiting technologies, creating opportunities for certificate falsification and modification of learning hours [2]. In recent years, the integrity of certification in the education and training sector has faced challenges, including the creation of counterfeit teacher qualification certificates and unauthorized trading of teaching credentials. These practices complicate educational management processes and make it difficult to accurately verify genuine learning achievements. Additionally, data in centralized databases may be exposed to risks of unauthorized changes.

(4) Significant deficiency in process documentation: Most existing records only document learning "outcomes," such as a graduation certificate, while neglecting the more critical "process." Key aspects—including teachers' attendance during training, classroom interaction, practical performance, group collaboration, and reflective summaries—serve to comprehensively reflect their learning attitudes and capacity development, yet are

largely overlooked [3]. This results in flat documentation that fails to provide a multidimensional portrayal of teachers' professional growth trajectory.

3. Current Status of Lifelong Learning Record Management for Early Childhood Physical Education Teachers

Currently, the management of lifelong learning portfolios for early childhood physical education teachers remains primitive, fragmented, and inefficient, as evidenced by the following aspects:

(1) Mixed archival formats and outdated management practices: The learning records of the vast majority of teachers exist in a coexistence of "paper file folders" and "scattered electronic spreadsheets within the school." The paper components include various completion certificates, honor certificates, training notices, and handwritten notes obtained from different training institutions [1]. The electronic components may consist of Excel spreadsheets or simple databases maintained by the school's personnel department or teaching research groups on local servers, used to record training hours for officially organized programs. This management approach relies heavily on manual entry and storage, resulting in low efficiency and a high risk of errors and loss.

(2) Training certificates are scattered and lack unified collection: The sources of training for early childhood physical education teachers are highly diverse, potentially including teacher training schools at the district/county level, municipal education institutes, continuing education colleges within universities, various sports associations, and even commercial children's physical fitness training companies. Each institution operates its own system for certificate issuance and management [4]. The certificates accumulated by teachers throughout their careers are varied and dispersed among individuals, never effectively centralized or managed. This makes it difficult for teachers themselves to present a complete and clear account of their entire learning journey when needed.

(3) The "Evidence-Demonstration Challenge" in Career Mobility and Promotion: When teachers need to transfer positions, participate in professional title evaluations, apply for key teacher positions, or seek higher-level appointments, they often face significant difficulties in presenting evidence of their qualifications. They must sift through a pile of disorganized paper documents to locate relevant certifications and hope that the competent authorities will recognize their validity. Due to the absence of an authoritative, unified platform accessible for instant verification, the value of teachers' learning achievements and professional development trajectories is significantly diminished [4]. For instance, the learning outcomes of an outstanding teacher who has completed extensive high-quality training in Region A may not be fully recognized in Region B, severely undermining their motivation for continuous professional development.

4. Analysis of the Compatibility between Blockchain Traceability and Lifelong Learning Profiles

4.1. Decentralized Distributed Ledger: From "Information Silos" to a "Consensus Network"

(1) Technical Characteristics: Blockchain operates as a distributed database or ledger without reliance on a centralized server, maintained and updated collaboratively by multiple equal nodes across the network. Any data entry requires consensus validation from the majority of nodes; once validated, the data is broadcast to all nodes, each preserving a complete and consistent copy of the ledger [2]. This directly addresses the critical issue of severe siloing in current learning record management systems.

(2) Breaking down barriers and achieving mutual recognition: When a training institution records a teacher's training experience, this record is validated through consensus and stored on the blockchain, synchronized across all nodes [5]. Its authenticity and validity are collectively verified by the network, establishing a basis for cross-institutional recognition. Teachers' learning outcomes are no longer devalued due to

institutional barriers, thereby achieving the principle of "one record, universal recognition."

(3) Enhanced system robustness: The absence of a central server ensures that the system remains operational and data remains intact even in the event of a single point of failure, such as a server outage at a school. As long as nodes are active within the network, all archival data remains secure and accessible, significantly enhancing the stability and durability of archive management [6].

4.2. Immutability and Timestamp Traceability: From "Difficult to Verify Authenticity" to "Irrefutable Evidence"

(1) Technical Characteristics: Blockchain employs cryptographic hash functions to package data into "blocks," with each new block containing the hash value of the previous block, forming an interconnected chain. This chain structure makes modifications to historical data highly challenging, as altering a block would change the hash values of all subsequent blocks, and such changes are immediately detected and rejected by other nodes in the network. Additionally, each block contains a timestamp that accurately records the data writing time, providing a robust technical solution for ensuring data authenticity [7].

(2) Preventing forgery and alteration: Once any learning record (whether certificate information or process-related data) is recorded on the blockchain, it cannot be unilaterally deleted or modified. This ensures that practices such as unauthorized changes to certificates or credit hours are technically infeasible. When verifying an on-chain certificate, employers or accreditation bodies need only confirm the existence and consistency of its records on the blockchain to achieve reliable authenticity verification [8]. This fundamentally redefines the trust foundation for teacher profiles.

(3) Establishing a clear growth trajectory: The timestamp feature leaves an indelible temporal mark on each learning record. By sequencing all teachers' learning activities chronologically, a clear, comprehensive, and traceable professional development timeline can be established. This provides significant value for evaluating teachers' long-term career progression, learning continuity, and knowledge update speed [6].

4.3. Smart Contracts: From "Manual Review" to "Automatic Execution"

A smart contract is a piece of code deployed on the blockchain that defines the rights, obligations, and business logic among participants [9]. When predefined conditions are met, the smart contract automatically executes the corresponding actions without requiring human involvement, ensuring transparency and effectively enhancing efficiency and fairness.

(1) Automated Certificate Issuance and Credit Conversion: Smart contracts can be developed to define completion criteria for specific training programs. For example, "when Teacher A's attendance rate reaches 95% and all module assessments score above 80, the system automatically issues a digital token representing a completion certificate to their account." Similarly, cross-institutional credit recognition rules can be encoded into smart contracts, enabling automated and reliable credit conversion while eliminating cumbersome manual reviews and potential inconsistencies.

(2) Refined process data recording: Smart contracts can automate the recording of complex process-related data. They are designed to receive scoring data submitted by examiners (whose identities are verified via private key signatures), automatically calculate average scores, and publish the final results on the blockchain alongside evaluation criteria. This ensures the standardization and objectivity of process-based assessments.

(3) Incentive Mechanism Design: Smart contracts can be employed to establish incentive mechanisms [1]. For instance, when teachers complete a challenging training program or make outstanding contributions in teaching research activities, the smart contract can automatically award them digital credentials such as "credits" or "achievement badges," thereby fostering their intrinsic motivation for continuous learning.

4.4. Asymmetric Encryption and Digital Identity: From "Passive Management" to "Autonomous Control"

(1) Technical Characteristics: Each participant in a blockchain network possesses a pair of keys generated using asymmetric algorithms: a public key and a private key. The public key serves as a publicly accessible identifier for receiving information, while the private key acts as a secret key stored by the owner for signing and authorization purposes [10]. Anyone can use the public key to encrypt information and send it to the owner, but only the owner can decrypt and read it using their private key. Additionally, the owner can use the private key to digitally sign the information, which others can verify using the public key, thereby enabling individuals to manage their own data securely.

(2) Establishing teachers' digital identities (DIDs): Each teacher has a unique digital identity in the system controlled by their key pair [11]. All learning records are linked to this identity address, forming their personal on-chain profile.

(3) Grant teachers control over their data: As the sole holder of their private keys, teachers are also the exclusive controllers of their own learning records. The record data is encrypted by default; unless signed and authorized by the teacher using their private key, no third party (including kindergartens or education authorities) can access its details. This design ensures that both management authority and ownership of the records remain with the teachers themselves.

(4) Achieve secure and controllable sharing: When teachers need to present their learning records to an employer, they no longer have to submit a batch of paper copies. Instead, through the system, they can use a private key to authorize the employer's public key, granting access to specific content in their records in read-only mode for a defined period [12]. The authorization record itself can also be recorded on the blockchain, ensuring traceability of the sharing process. This not only facilitates teachers' work but also safeguards data security and privacy.

5. Construction of a Learning Portfolio System Framework Based on Blockchain Traceability

5.1. System Design Objectives

This system aims to establish a secure, trustworthy, efficient, and open lifelong learning ecosystem for early childhood physical education teachers, with the following core design objectives:

(1) Trustworthiness: Ensures that all recorded learning data (including processes and outcomes) are authentic, valid, tamper-proof, and fully traceable, fundamentally addressing trust issues [13].

(2) Completeness: Supports recording diverse learning formats, including not only formal training certificates but also detailed documentation of attendance, hands-on practice, seminars, and online learning activities, thereby creating a comprehensive 360-degree learning profile for teachers.

(3) Data Ownership: Empowers teachers to manage, authorize, and share their lifelong learning portfolios independently, thereby strengthening their central role in professional development.

(4) Shareability: While safeguarding data privacy, establish a mechanism for mutual recognition and secure sharing of data among stakeholders (kindergartens, training institutions, and education authorities), eliminate information silos, and facilitate the circulation of learning outcomes value [6, 11].

(5) Scalability: The system architecture should possess robust scalability, enabling seamless integration of additional participating institutions in the future, supporting a wider range of archival data types, and ensuring interoperability with other educational information systems (e.g., human resources management systems, credit banks).

5.2. System Participants and Roles

Early childhood physical education teachers are the primary users of the system and the ultimate owners of their records. They are responsible for creating and managing their

digital identities, accessing their learning profiles, and authorizing others to view these profiles through personal terminals such as apps or web portals.

Training institutions serve as providers of learning content and initial issuers of learning records. Acting as nodes within the consortium blockchain, they are tasked with recording data related to teachers' training processes, such as attendance and assessment scores, as well as final learning outcomes like digital certificates [4]. Their credibility is endorsed by educational authorities.

Kindergartens or employers function as users and verifiers of learning records. As nodes on the consortium blockchain, they can, with teacher authorization, query and verify the learning records of applicants or current teachers. This capability supports recruitment, performance evaluation, promotion, and the development of in-service training programs.

Education authorities act as systemic regulators and governance bodies [5, 6]. As key nodes in the consortium chain, they are responsible for establishing data standards, certifying and managing the qualifications of participating entities such as training institutions and kindergartens, maintaining ecosystem rules and order, and conducting macro-level data analysis and supervision.

Third-party evaluation agencies provide professional skill assessments. For instance, specialized sports skill rating organizations can join the network as nodes to conduct independent practical competency evaluations for teachers and publish the results on the blockchain, thereby enhancing the comprehensiveness and authority of teacher profiles.

5.3. Overall System Architecture

The architecture is designed to meet these objectives by utilizing established blockchain application design patterns and organizing its structure into six distinct layers.

5.3.1. Infrastructure Layer

This layer forms the physical backbone of the system, consisting of servers hosted by participating entities such as education authorities, major kindergartens, and core training institutions, or utilizing purchased cloud services. It delivers essential computing, storage, and network resources required for the operation of the blockchain network [3].

5.3.2. Data Layer

The data layer utilizes a hybrid storage model that integrates on-chain and off-chain methods to achieve an optimal balance of efficiency, cost, and security.

On-chain data refers to the blockchain ledger itself, which stores critical information requiring strong consensus and immutability. Examples include user digital identities (DIDs), hash values of learning records (data fingerprints), digital certificates, smart contract addresses, and authorization records. These datasets are characterized by their small volume but high value density [3].

Off-chain data involves the storage of original, large-volume archival files using distributed file systems (e.g., IPFS) or authorized centralized cloud storage [5]. Examples include training materials, instructor presentation videos, detailed grading sheets, and learning reflection documents. When uploaded, each file generates a unique hash value that is stored on the blockchain. This ensures the tamper-proof integrity of the original files, as hash values are immutable, while also preventing the blockchain from becoming overloaded and inefficient due to excessive data storage.

5.3.3. Network Layer

The network layer facilitates communication between nodes by employing a peer-to-peer (P2P) network protocol [12]. This protocol enables nodes to broadcast transactions and synchronize block data, ensuring the distributed ledger remains consistent and performs in real time.

5.3.4. Consensus Layer

This constitutes the core of blockchain, defining how nodes reach consensus on the validity of new blocks [3]. In this system, since participants are licensed and relatively

trustworthy entities, a higher-performance, more energy-efficient non-workload proof consensus mechanism—such as Practical Byzantine Fault Tolerance (PBFT)—is employed. PBFT ensures the system continues to operate normally and consistently even when a small proportion of nodes fail or act inappropriately.

5.3.5. Contract Layer

This layer hosts smart contracts that define the system's core business logic. The series includes: DIDManage Contract, which is responsible for registering and managing digital identities for roles such as teachers and institutions; Process Record Contract, which logs procedural data, including operations like QR code check-ins, homework submissions, and online tests, all of which invoke this contract to record transactions; Certificate Issue Contract, which defines the conditions for certificate issuance, enabling training institutions to call this contract to generate unique, tamper-proof digital certificates for teachers; and Access Control Contract, which manages data access permissions, allowing teachers to specify which users (identified by public keys) may access specific content in their profiles during designated time periods.

5.3.6. Application Layer

Facilitates interaction with the contract layer through API interfaces, simplifying complex technical processes into accessible and user-friendly functionalities.

The Teacher Portal/App includes a personal portfolio feature, enabling teachers to access learning records, manage digital certificates, authorize sharing, and review competency radar charts [10].

The Institution Management Platform, designed for training institutions and kindergartens, allows for the publication of training courses, monitoring of learner progress, issuance of certificates, creation of verification requests, and access to authorized teacher profiles [1].

The Regulatory Dashboard, tailored for education authorities, offers detailed statistical analyses of nationwide data, such as average teacher training hours by region, popular training programs, and certification issuance metrics, aiding in data-driven decision-making [2].

5.4. Design of Core Business Processes

5.4.1. Identity Registration and Authentication Process

Step 1: The teacher or institution submits a certification application to the relevant education authorities.

Part 2: The education authority evaluates the applicant's qualifications. Upon approval, it utilizes DIDManageContract to generate a unique digital identity (DID) on the blockchain and establishes a public-private key pair. The private key is securely distributed to the user.

Part 3: After receiving their digital identity, users, including teachers and institutions, can access the system to perform various authorized tasks.

5.4.2. Blockchain-Based Data Processing Workflow for Learning (Using an Offline Hands-On Session as Example)

Step 1: During the class session, the teacher utilizes a mobile application to scan the dynamic QR code provided by the training institution. The application signs the check-in details, including course ID, time, and location, using the teacher's private key and transmits this information to the training institution's node [1].

Second data packaging step: Once the training institution node verifies the signature, it invokes the ProcessRecordContract and submits the check-in record as a transaction to the blockchain network [3, 9].

Part 3: Consensus and Blockchain Registration: Consensus nodes within the network, such as other institutions or educational authorities, execute the PBFT consensus algorithm to validate the transaction. Upon achieving consensus, the transaction is incorporated into a new block and permanently stored on the blockchain.

Performance recording in Part IV: During the course, instructors utilize tablets to evaluate practical performance. Upon submission of the evaluation forms, the data undergoes a process of signature, packaging, and consensus verification. The hash value and key outcomes, such as the total score, are recorded on the blockchain and associated with the instructor's DID.

5.4.3. Learning Outcomes Certification and Release Process

The first condition is met when the instructor has successfully completed all modules of the training program [4]. Confirmation is provided by the system backend monitoring program or the training institution administrator, ensuring the instructor fulfills all graduation requirements outlined in the CertificateIssueContract, such as completing the required hours and passing assessments.

Step 2: Contract invocation -- The training institution utilizes its private key to activate the CertificateIssueContract, supplying the teacher's DID and certificate details, including course name, level, and issuance date [2].

Step 3: Certificate Generation -- The smart contract processes the information to create a unique, non-transferable digital certificate, typically in the form of an NFT, which is then stored at the teacher's profile address on the blockchain.

Step 4 (Teacher Verification): Teachers can access their app to view the newly issued, publicly verifiable digital certificate under the "My Certificates" section [5].

5.4.4. Archive Inquiry and Authorization Verification Process

Step 1: Teacher Authorization: Teacher A applies for a position at Kindergarten B. Kindergarten B sends a file access request to Teacher A via its institutional account [2]. Teacher A receives the request through their app, approves it, and sets the authorization period to seven days with the scope of "viewing all training certificates and practical assessment scores."

Step 2: Chain Authorization: Teacher A signs the authorization using their private key, and the system invokes the AccessControlContract to record this authorization rule (authorizer A, authorized party B, authorization details, validity period) on the blockchain [10].

Step 3: Employer Inquiry: The recruitment staff of Kindergarten B access their management platform to view Teacher A's profile. The platform submits an inquiry request to the blockchain node.

Step 4: Verification and Display: The blockchain node verifies whether the Access Control Contract contains valid authorization from Party B to Party A. Upon successful verification, the node retrieves the relevant data from both on-chain and off-chain sources (using on-chain hash verification to ensure file integrity), decrypts it, and displays it to Kindergarten B. Each record viewed by Kindergarten B includes a traceable source, specifying the issuing authority and timestamp, to ensure authenticity.

5.4.5. Technical Considerations

Blockchain Platform: The consortium blockchain model is recommended. As the number of participants in this scenario is limited and requires authorization, the consortium blockchain provides enhanced transaction performance, superior privacy protection, and more flexible governance capabilities while retaining its decentralized advantages [1, 11].

Consensus mechanism: PBFT or its variants (e.g., Raft) are utilized. These mechanisms eliminate the need for mining, offer rapid confirmation speeds (within seconds), and consume minimal energy, making them ideal for high-frequency trading scenarios in consortium blockchains.

Smart Contract Language: The choice of language depends on the selected platform. For instance, when using Hyperledger Fabric, chaincode can be written in widely used languages such as Go, Node.js, or Java.

Off-chain storage: IPFS (InterPlanetary File System) is recommended. This peer-to-peer distributed file system generates unique hash addresses based on file content [5, 11].

Storing files on IPFS not only facilitates decentralized storage but also ensures that file contents remain immutable once uploaded, aligning seamlessly with blockchain's inherent characteristics.

By establishing this systematic framework, an abstract technical concept can be transformed into a concrete, operational application system capable of addressing real-world challenges [6]. This approach lays a solid foundation for ensuring the reliable traceability of lifelong learning records for early childhood physical education teachers.

6. Conclusion

The lifelong learning portfolio for early childhood physical education teachers based on blockchain traceability represents not only an innovative advancement in traditional portfolio management but also a meaningful shift in the paradigm of teacher professional development. Although challenges remain, its potential value warrants continued exploration and implementation. In the near future, this technology may provide a reliable data foundation and trust mechanism for supporting the development of a high-quality, professional workforce of early childhood physical education teachers.

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