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Research on the Path of Microcertification Integrated into Kindergarten Teachers' Individualized Professional Development

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Abstract Micro-certification, as an emerging competency certification method, has the advantages of strong flexibility and high relevance. In order to solve the problem of unclear personalized professional development path for kindergarten teachers, this study constructs a micro-certification system based on blockchain technology, and adopts a quasi-experimental research methodology to carry out a two-school-year practical study in two kindergartens in a city. The study uses the federal learning algorithm, differential privacy protection mechanism and other technical means to design a four-layer system architecture with a multimodal resource presentation layer, a data management layer, an online learning input analysis layer, and a visualization display layer. By analyzing the pre and post-test data from 128 valid questionnaires, the results show that: the paired-sample t-test Sig values for the five dimensions of teacher professional development are all 0.000, which is significantly lower than the 0.05 significance level; the decentralized federated learning model based on differential privacy increases the running time by only 0.19-0.22 seconds per round on the MLP MNIST dataset; and the system communication overhead in the case of 10 users participated reached 28.04M; the t-test value of the effect of teachers' overall professional level improvement was -19.115. The study confirms that the micro-certification system can effectively promote the personalized professional development of kindergarten teachers, and provides a feasible path to build a digital teacher education ecosystem.

Index Terms Micro-authentication, personalized professional development, blockchain technology, federated learning, differential privacy, kindergarten teachers

I. Introduction

Kindergarten is an important place for children to enter pre-school education, which is not only a place for children to learn knowledge and acquire skills, but also an important platform for children's growth [1], [2]. In modern society, the requirements for primary school students or even students in the last semester are getting higher and higher, and the children's learning pressure is also getting higher and higher, which highlights the importance of kindergarten education even more [3], [4]. With the rapid development of early childhood education in China, the professional development of kindergarten teachers has become more and more important [5]. Kindergarten teachers are responsible for the important role of enlightenment education, and their professional ability and quality are directly related to the quality of kindergarten education and the growth and development of young children [6], [7]. Scientific planning of the professional development path of kindergarten teachers to improve their comprehensive quality and professional competence has become an important issue that needs to be solved in the field of kindergarten education, and micro-credentialing lays the foundation for the realization of this goal [8]-[10].

Micro-certification is a new type of qualification that has emerged in the field of education and professional development in recent years, and its essence is to obtain proof of skill level through short-term, specialized learning or practice [11], [12]. Compared with traditional academic certificates or practice vocational qualification certificates, micro-certification pays more attention to the mastery and application of specific skill points, emphasizes result orientation, and has the characteristics of fine granularity, short cycle, and high flexibility [13]-[15]. Kindergarten teacher micro-competency certification, as an implementation program for teaching enhancement, has attracted widespread attention in the education sector in recent years, and the content of the certification covers all aspects of early childhood education, involving teaching skills, professional knowledge, educational philosophy and other aspects [16]-[19]. Through certification, the teaching level of teachers can be improved, which helps to strengthen the individualized professional development of the kindergarten teaching force [20], [21].

This study proposes to construct a path system for micro-certification to be integrated into kindergarten teachers' personalized professional development. The study firstly, clarifies the intrinsic connection between micro-certification and teachers' personalized professional development through theoretical analysis, and constructs a theoretical framework; secondly, designs the micro-certification system architecture using blockchain technology, and adopts advanced algorithms, such as federated learning and differential privacy, to ensure the system's security and validity; thirdly, based on the theory of decomposition of competencies, the kindergarten teacher's professional competencies are subdivided into certifiable micro-competency units; and finally, through a quasi-experimental Finally, the practical effect of the system is verified through quasi-experimental research to provide empirical support for the popularization and application.

II. Microcredentialing and individualized professional development of teachers

II. A.Micro-authentication

Microcertification is an electronic representation of educational achievement, similar to the badges and medals earned for skills training. Microcertifications represent an individual's completion of training or courses required by the organization issuing the certification. As such, micro-credentials can serve as a tool to demonstrate mastery of specific knowledge to coworkers, employers, or potential employers.

The micro-credentialing lifecycle is shown in Figure 1. When an individual or organization completes the learning tasks assigned by the microcertification issuer, based on course registration and grade information, the microcertification organization generates and releases a microcertification to the learner who has completed the objectives. After obtaining the micro-credential, the individual can display the micro-credential when needed (e.g., during the job application process). The person to whom the micro-credential is presented verifies the authenticity of the micro-credential as proof of the presenter's specialized knowledge or competence.

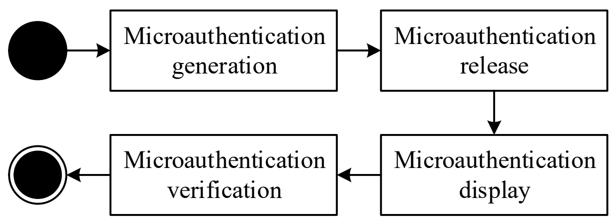

Figure 1: Schematic diagram of the microauthentication life cycle

II. B.Personalized Professional Development

There are relatively few theoretical studies on personalized teacher professional development and empirical studies on how to promote teachers' personalized teacher professional development. There is also little research on online platforms for teacher professional development, and how to utilize online learning platforms to enhance teachers' professional development is also a topic that needs to be studied.

This paper focuses on the application of micro-certification in improving the post-service learning environment of teachers and enhancing their teaching skills to promote the personalized professional development of kindergarten teachers.

II. B. 1) Individualized professional development for teachers

Teachers' personalized development is the sum of the more stable psychological and behavioral tendencies of the teacher's role combined with the teacher's own personality and manifested in educational activities [22]. It can be seen that the personalized development of teachers contains the dual attributes of specialization and personalization, and is a process in which the two go hand in hand. On the one hand, specialization is the solid foundation of individualization. Teachers are professionals who perform educational and teaching duties, and they need to have professional knowledge, professional skills and professional sentiment. The implementation of the teacher qualification system guarantees the professionalism of the teaching profession. If the “source of nutrition” of professionalization is left, the personalized development of teachers will become water without a source and wood without a foundation. On the other hand, individualization is the natural direction of professionalization. The ultimate goal of professionalization is not to cultivate identical teachers, but to provide more opportunities and space for teachers' personalized growth.

Teachers' personalized development refers to the endogenous potential and distinctive qualities of their professional development, including four aspects: knowledge, emotion, intention and action.

First, existing experience is the source of teachers' personalized development.

Secondly, teachers' moral cultivation is the cornerstone of teachers' personalized development.

Third, the sense of autonomy is the driving force of teachers' personalized development.

Fourth, teaching style is the embodiment of teachers' personalized development.

To sum up, teachers' personalized development is synchronized with professional development. As a complete natural person, teachers should pay attention to the organic unity of knowledge, emotion, intention and action when promoting teachers' personalized development.

II. B. 2) Individualized development pathways for kindergarten teachers

(1) Changing concepts and innovating mechanisms

This requires teachers and teaching evaluators to dare to break through the limitations of the lesson plan, to examine the lesson plan from different perspectives, and to understand the lesson plan from different levels. Schools and compilers of teaching materials should reserve space for users of teaching materials to “adapt”. In a textbook, the upper knowledge point is the goal, and the lower knowledge point and the connection between the lower knowledge points can be interpreted as an alternative path. The school's mechanism (teaching management, teaching evaluation, teaching assessment) should be adjusted accordingly.

(2) Mutual synergy and team building

At present, in many occasions, the leading role of the teacher is alienated to the “dominant role”. Teachers have not only become the decisive and isolated subjects of the class, but also used to go their own way and not communicate with each other. Even if there is occasional overlap in work, teachers are “in a hurry to come and go,” and when the work is done, they are separated.

Personalized professional development is not the same as isolated teaching, nor is it the same as decentralized teaching, but it is about breaking through the barriers between courses. One of the most important ways to reconfigure classroom teaching is to establish a community of teachers who teach. Teachers with different personalities inspire each other and complement each other's character within the community, inhibit the negative impact of personality traits, and improve professionalism in order to better improve the quality of teaching and educate and train students.

(3) Scientific and technological innovation to break through the circle

The fundamental measure to break the limitations of teachers' knowledge is scientific and technological innovation, to introduce mechanisms in the field of science and technology into classroom teaching, or to introduce teachers into the realm of science and technology. Technological innovation is the strongest foundation to support personalized teaching.

STI helps to stimulate teachers' individualized thinking and helps to create and implement distinctive teaching models. STI pursues excellence in nature and requires uniqueness and originality, inspiring teachers to condense teaching objectives, formulate teaching plans, improve teaching materials, update teaching methods, reform classrooms, reconstruct curricula, and innovate education and teaching modes in accordance with the latest developments in the discipline. Create a profound new knowledge space for students, win students' confidence in teachers' knowledge ability, and stimulate students' desire for knowledge and exploration. Enhance the practical ability of students, bring the distance between the classroom and the economy and society closer, improve the “use value” of the knowledge and ability mastered by students, and ensure the adaptability and competitiveness of graduates' employment.

II. C.Applicability of Microcertification to Individualized Professional Development for Teachers

Micro-certification, as a kind of miniature online learning activity, with its qualities of competence orientation, personalization, flexibility and low cost, high efficiency and ease of sharing, provides useful insights into the direction of online teacher education development, and is of great significance to the personalized professional development of kindergarten teachers.

(1) At the national level, it is conducive to the realization of the goal of lifelong learning and the construction of a learning society.

The digitalization of education is a new track and new impetus for “providing education to the satisfaction of the people”, and it is also a new initiative and new requirement for the construction of a lifelong learning society for all people and a learning country.

Digitalization of education is the integration of digital technology and education, digital transformation focuses on education reform and innovation based on digital technology, and realizes the deep integration of physical space and virtual space, online space and offline space with the help of digital technology. The application of digital transformation in the field of education creates favorable conditions for educational change, and also lays a solid foundation for the digital transformation of lifelong education.

Using micro-credentialing as a certification platform for online learning and the recognition of learning achievements can greatly promote the learning of primary and secondary school and kindergarten teachers, making more and more teachers join the ranks of lifelong learning, which is an effective way to realize the goal of lifelong learning and build a learning society.

Therefore, from the national level, the development of digital education is conducive to realizing the goal of lifelong learning and building a learning society.

(2) At the level of teacher development, it is conducive to promoting individualized professional development of kindergarten teachers.

Digitalization increases the system's intelligent identification ability, improves the accuracy and agility of its decisions and actions, and optimizes system development so that it can quickly respond to external changes and resolve the risks associated with uncertainty. With the development of digital technology, the field of education has opened the way to systematic, holistic and all-encompassing digital development. The establishment of a demand-driven digital education paradigm requires the construction of a digital learning ecosystem based on digital technology to provide kinetic energy for precise, customized and personalized education and learning.

Many kindergarten teachers will enter a period of burnout after a certain number of years of work, not knowing how to achieve further career development and lacking a certain degree of initiative in career development. The recognition of post-service continuing education learning outcomes is conducive to enhancing individual learning awareness and initiative.

Micro-credentialing is a bridge for personalized sharing of learning outcomes, transforming the results of post-vocational continuing education into officially recognized education certificates, which can be used as credentials for management accreditation and shared on social platforms. Moreover, micro-credentials can support storage and transfer between different platforms, and support the verification of skills as well as the recording of learning experiences, which is conducive to the formation of a good learning culture, stimulates individual motivation for lifelong learning, and helps kindergarten teachers to build up their self-confidence and stimulate their intrinsic interest in learning. Therefore, the use of micro-certification in the learning of post-service continuing education is conducive to the enhancement of their learning initiative and self-confidence at the individual level. It helps to realize the mutual conversion of skills in different fields, expands the breadth and depth of kindergarten teachers' learning, and has a certain relevance to the post-service professional development of kindergarten teachers.

III. Design of individualized professional development for teachers on microcredentialing projects

III. A. Design and development of the micro-credentialing program

Microcertification is both a competency-based certification approach and a teacher professional development paradigm. Thus, micro-certification program development includes not only the definition of certification competencies and the clarification of certification requirements, but also the provision of resources to support teachers' competency development, and the latter highlights the value and role of micro-certification in supporting teachers to carry out practice and practice-based competency development.

The design of the development process of personalized professional development micro-certification for kindergarten teachers in this paper mainly includes three steps: decomposing the competencies to form a collection of micro-competencies, clarifying the micro-competency requirements to design the certification framework, and identifying the conditions for micro-competency development to develop support resources.

The design and development framework of the micro-certification program is shown in Figure 2.

The project design based on the competency standards can not only reflect the core requirements of teachers' IT application competency development in the coming period, but also provide a more complete and systematic competency development map for teachers' professional development. In addition, it can also achieve the purpose of unifying the benchmarks of each link in the design process. It should be noted that research-based is both the internal self-awareness of micro-credentialing as a basis for competency development and the external requirements of micro-credentialing for the manifestation of its scientific nature.

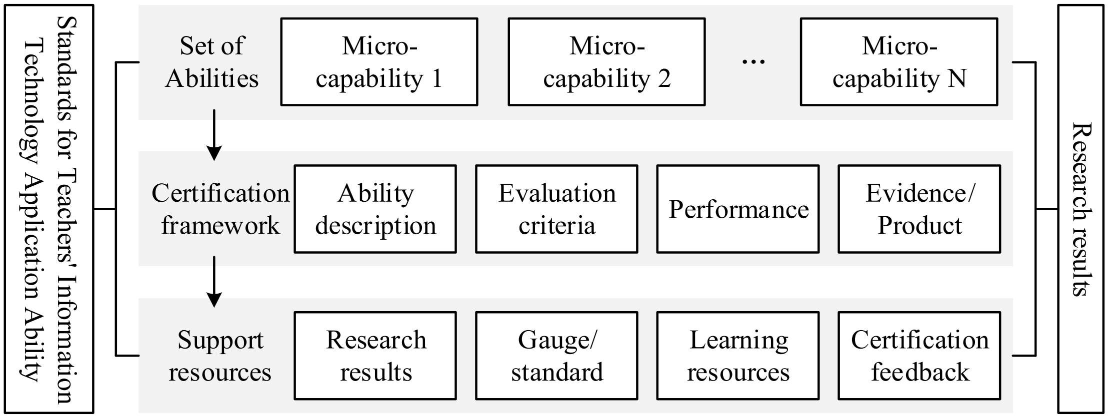

Figure 2: Design and development framework of the microauthentication project

III. B. Blockchain-based micro-authentication system architecture design

The current micro-authentication systems all adopt a centralized architecture, storing data in traditional databases, which are vulnerable to attacks to form a single point of failure, resulting in micro-authentication fraud (i.e., the micro-authentication data is tampered with, and the authenticator is not sure of the authenticity of the micro-authentication). Therefore, in this paper, decentralized blockchain technology will be introduced into the existing micro-authentication system architecture to improve system security [23].

III. B. 1) Design objectives

In this paper, we will propose a blockchain based micro-authentication system architecture with reusable micro-authentication related services in the architecture. The requirements of the target architecture are as follows:

(1) The micro-authentication provider can record the information of micro-authentication objects in its daily work.
(2) The micro-authentication provider generates micro-proofs based on the recorded information.
(3) Provide micro-authentication verifiers with convenient and effective micro-proof verification methods.
(4) The system architecture should ensure data privacy and integrity.
(5) Ensure the availability of the underlying system architecture.

III. B. 2) Architectural design

The blockchain-based micro-authentication system architecture adopts a 3-layer structure: user interface layer, service layer, and infrastructure layer. The service layer includes: deployment service, account management service, data management service, and micro-authentication management service. The infrastructure layer includes: traditional database and blockchain network (and smart contracts running on blockchain). The target users of the system include: micro-authentication providers (e.g., schools), micro-authentication objects (e.g., students), and micro-authentication verifiers.

III. B. 3) Blockchain algorithms

(1) Federated Learning

Federated learning is essentially a distributed machine learning. Suppose there are N participants using local dataset $\{D_i\}_{i=1}^{N}$ to collaborate in training machine learning models. The traditional machine learning approach is to collect all the data to the server side, and the server iteratively trains to get the machine learning model w_G. However, in federated learning, the participant trains the model using local data, securely transmits the local model parameters to the server, and the server aggregates the local models into a global model w_G.

The specific steps of federated learning model training are as follows:

Step 1: The central aggregation server initializes the model parameters.

Step 2: The central server securely transmits the initialized model parameters to each client participating in the training.

Step 3: After receiving the global model parameters w_G, the clients use the local dataset D_i for training, and update the local model parameters w_i through the optimization algorithm so that the loss function is minimized.

Step 4: Clients participating in training transmit the trained local model parameters w_i securely to the central server, wait for the central server to aggregate the global model to start a new round of local training, and so the cycle iterates to continuously improve the performance of the model.

Step 5: The central server aggregates N local model parameters according to the following formula, and finally obtains the global model parameters w_G . When aggregating, the Federal Average (FedAvg) algorithm is generally used, i.e., the global model parameters are obtained by calculating the weighted average of the model parameters uploaded by each client. I.e:

$$w = \frac{1}{N}\sum_{i=1}^{N} w_i \tag{1}$$

where w_i is the local model parameters uploaded by the i th client. w is the aggregated global model parameters, and N is the number of clients involved in training.

During the training process, steps 2 to 5 are iterated until the model converges or reaches a set maximum number of iterations.

In federated learning, the gradient descent algorithm (SGD) is widely used to minimize the loss function for model parameter updating. The local loss function of the participant is denoted as $L(D,w)$ and the minimized loss function is as:

$$w^* = \arg\min \sum_{i=1}^{N} L_i(D_i, w) \tag{2}$$

Assuming that D_m represents the data held by client m, a complete training dataset D should consist of (I,Y,X) . I represents the sample ID, Y represents the label information of the dataset, and X represents the feature information of the dataset. Both the feature information and the sample ID of the data owned by different participating parties may be different. Based on the difference of data distribution of participating clients, federated learning is categorized into horizontal federated learning, vertical federated learning and federated migration learning.

Horizontal federation learning is characterized by the same dataset feature X and labeling information Y, but different sample IDs, which is expressed by the formula as:

$$X_m = X_n, Y_m = Y_n, I_m \neq I_n, \forall D_m, \forall D_n, m \neq n \tag{3}$$

Longitudinal federated learning is characterized by different features X and label information Y for each dataset, but the same sample ID information, which is expressed in the formula as:

$$X_m \neq X_n, Y_m \neq Y_n, I_m = I_n, \forall D_m, \forall D_n, m \neq n \tag{4}$$

Federated Migration Learning is characterized by different dataset features X, label information Y, and sample ID information, which are expressed as in the formula:

$$X_m \neq X_n, Y_m \neq Y_n, I_m \neq I_n, \forall D_m, \forall D_n, m \neq n \tag{5}$$

(2) Differential Privacy

Differential privacy is a technique to protect data privacy by adding noise to the data.

Definition 1: Adjacent datasets. Given two datasets D and D', D and D' are neighboring if D' is obtained by adding or removing an individual data item from D.

Definition 2: Differential Privacy. A randomized algorithm M is said to satisfy $(\varepsilon,\delta)-DP$ if it satisfies the following equation for two neighboring datasets D and D', and for any subset S of the set of outputs of M. To wit:

$$P(M(D) \in S) \leq e^{\varepsilon_1} \times P(M(D') \in S) + \delta \tag{6}$$

In this case, the privacy budget ε is a parameter that controls the degree of privacy leakage, with a smaller ε implying stricter privacy protection.

Definition 3: Sensitivity. If there exist two neighboring datasets D and D', and a function or query $f: D \to R^k$, the sensitivity Δf of the function or query f can be expressed by the following equation:

$$\Delta f = \max_{D,D'} \| f(D) - f(D') \| \tag{7}$$

where $\|\cdot\|$ denotes a paradigm, usually an Ll-paradigm or L2-paradigm. $f(D)$ and $f(D')$ denote the output of the function or query on the data sets D and D', respectively. The Δf denotes the maximum variation of the function or query f, i.e., the maximum difference between the output results of the function or query on the data sets D and $D^{'}$ that differ by one data item. Larger sensitivities imply that the query results are more sensitive to small changes in the individual data, and thus require the addition of greater noise to protect privacy. Conversely, if the query is less sensitive, less noise can be added.

The mechanisms for implementing differential privacy include a series of mathematical methods and algorithms, mainly Laplace, exponential and Gaussian mechanisms. In terms of processing data types, the Laplace mechanism and Gaussian mechanism are mainly used to process numerical data, while the exponential mechanism is more suitable for processing discrete data.

Laplace mechanism: Let the query function $f: D \rightarrow R^k$, where D is the data domain and R^k is the k-dimensional real number space. For any input $x \in D$, the Laplace mechanism adds Laplace noise to the query result $f(x)$ to preserve privacy, i.e.:

$$A(x) = f(x) + Lap(\frac{\Delta f}{\varepsilon}) \tag{8}$$

where Δf is the global sensitivity of the query function f and ε is the privacy budget parameter. It can be seen that the amount of noise added by the Laplace mechanism is proportional to the sensitivity Δf and inversely proportional to the privacy budget ε.

(3) Differential privacy based on Gaussian processes

Definition 4: Relaxed differential privacy. For any two neighboring datasets D and $D^{'}$, given some randomization algorithm F, apply it to the neighboring datasets D and $D^{'}$, respectively, as satisfied:

$$\Pr[F(D) \in S] \le e^{\varepsilon} \times \Pr[F(D^{'}) \in S] + \delta \tag{9}$$

Then it is called $(\varepsilon, \delta)-$ differential privacy. Compared to strict $\varepsilon-$ differential privacy, this formula has an additional term δ, which denotes the slack term, i.e., the probability of being able to tolerate δ does not satisfy strict $\varepsilon-$ differential privacy.

In practice, Gaussian mechanisms are often used to provide $(\varepsilon, \delta)-$ differential privacy protection.

Definition 5: Gaussian mechanism. For a mapping act f, if the randomization algorithm F is:

$$F(x) = f(x) + N(0, \sigma^2) \tag{10}$$

where $N(0, \sigma^2)$ denotes noise obeying a Gaussian distribution. If $\sigma \ge \frac{c\Delta f}{\varepsilon}$ is satisfied and $c \ge \sqrt{2\ln(\frac{1.25}{\delta})}$. Then it is guaranteed that $(\varepsilon, \delta)-$ differential privacy preservation can be provided. The specific proof procedure is given in detail in the foundation of Dwork's differential privacy algorithm, and a rough proof framework is listed here as follows:

$$\begin{aligned} \Pr_{n-N(0,\sigma^2)}[f(x)+n \in S] &= \Pr_{n-N(0,\sigma^2)}[f(x)+n \in S_1] + \Pr_{n-N(0,\sigma^2)}[f(x)+n \in S_2] \\ &\le \Pr_{n-N(0,\sigma^2)}[f(x)+n \in S_1] + \delta \\ &\le e^{\varepsilon}(\Pr_{n-N(0,\sigma^2)}[f(x)+n \in S_1]) + \delta \end{aligned} \tag{11}$$

(4) Decentralized federated learning model based on differential privacy

In the decentralized federated learning model, the model parameters of all participants during each round of training are saved in the blockchain for the remaining nodes to verify and review. Therefore, any participant can obtain the model parameters of the remaining participants in each round of training. However, it has been recently shown that an attacker can infer labels from the shared model parameters and recover the original training samples without any prior knowledge about the training set. Based on the introduction of differential privacy, differential privacy can protect users' privacy from disclosure to some extent. Therefore, in this paper, we will propose a decentralized federated learning model based on differential privacy protection. In this paper, we define a federated learning aggregation algorithm that satisfies $(\varepsilon, \delta)-$ differential privacy protection.

The full process of decentralized federated learning aggregation algorithm based on differential privacy is as follows:

First define the local initialization model of each participant $\tilde{w}_1^0, \tilde{w}_2^0, ..., \tilde{w}_{N-1}^0, \tilde{w}_N^0$, the initialization models can be the same or different depending on the scenario the participants face. During the t th round of iteration, N participants train the model using the local dataset to obtain the local model parameters w_i^{t+1}. Noise n_i^{t+1} is added to the local model parameters to obtain the noise-added model w_i^{t+1} and then transactions are generated and sent to the remaining participants. When a new block is generated, participants calculate the weight of the correlation between the local model and the rest of the model parameters in the new block, and aggregate the model parameters according to the different weights to get the local personalized model $\tilde{w}_i^{t+1}$.

Next, this paper will elaborate on the specifics within the noise term proposed in the algorithm as well as prove its ability to satisfy the $(\varepsilon,\delta)-$ differential privacy preservation requirement. From the differential privacy preservation of the Gaussian mechanism above, it is known that the size of the added Gaussian noise depends on the global sensitivity of the function. First, in order to ensure differential privacy, the impact of local model updates must be limited, i.e., pruning is required for each round of model parameter updates.

In this paper, the pruning threshold of w_i^t is specified to be S, i.e., the magnitude of each model parameter update must not exceed S.

During local model training, the mapping behavior f can be defined as follows:

$$\begin{aligned} f_i \square\ w_i' &= \arg\min_{w_i'}(loss(w,D_i)) \\ &= \frac{1}{|D_i|}\sum_{j=1}^{m_i}\arg\min_{w_i'}(loss(w,D_{i,j})) \\ &= \frac{1}{m_i}\sum_{j=1}^{m_i}\arg\min_{w_i'}(loss(w,D_{i,j})) \end{aligned} \tag{12}$$

where D_i denotes the local dataset of the i th participant, m_i denotes the size of its dataset, and $D_{i,j}$ denotes the j th data in its dataset. In this way, its global sensitivity is:

$$\begin{aligned} \Delta f_i &= \max_{D,D}\left\| f_i(D_i) - f_i(D_i') \right\|_1 \\ &= \max_{D,D_i}\left\| \frac{1}{D_i}\sum_{j=1}^{m_i}\arg\min_{w_i}(loss(w,D_{i,j})) - \frac{1}{|D_i'|}\sum_{j=1}^{m_i}\arg\min_{w_i'}(loss(w,D_{i,j}')) \right\|_1 \\ &= \frac{2S}{|D_i|} \\ &= \frac{2S}{m_i} \end{aligned} \tag{13}$$

where D_i' is the neighboring dataset of D_i. Thus the parameters of the noisy local model uploaded for participant i can be expressed as $\tilde{w}_i^t = w_i^t + n_i^t$, where $n_i^t \sim N(0,\sigma_c^2), \sigma_c = \frac{2cS}{\varepsilon m_i}, c \ge \sqrt{2\ln(\frac{1.25}{\delta})}$.

III. C. Decomposition of kindergarten teachers' individualized professional development

In addition to a credible and mature standardized basis, the decomposition is also a difficult issue, as on the one hand, the decomposed competency should be able to cover the main content and requirements of the competency. On the other hand, the micro-competency formed by decomposition also needs to have the characteristics of observable, assessable and relatively independent. In management research, the relationship between competencies and sub-competencies is often represented by tree hierarchies, which can simplify the management of competencies, but also affects the flexibility and reusability of competencies. In order to overcome this shortcoming, a competency modeling approach based on multidimensional tree structure is proposed.

With reference to the above multifaceted analysis, this paper proposes to carry out competency decomposition taking into account the needs of organizational perspective, competency perspective as well as pedagogical perspective, i.e., while decomposing the competencies, it takes into account the requirements of the teacher's role, the definition of the teacher's competencies as well as the teacher's pedagogical context.

The basic idea of individualized professional competence decomposition for kindergarten teachers is shown in Figure 3. Competencies must be defined in relation to specific tasks and manifested through teachers' physical, interpersonal, and psychological behaviors.

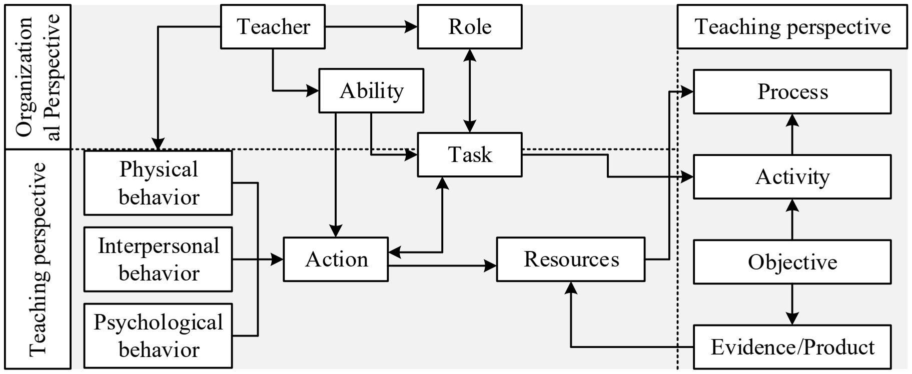

Figure 3: The idea of the teacher's individualized professional ability to break down

III. D. Blockchain-based micro-authentication system construction for teachers' personalized development

Evidence is the most direct and effective proof for the accurate improvement and evaluation of kindergarten teachers' personalized professional development. The cultivation of kindergarten teachers' personalized professional development needs to fully combine the “evidence-based” thinking of micro-authentication and the educational attributes of blockchain technology, and take the in-depth fusion of the two as the development path to build an “evidence-centered, competency-oriented, safe and trustworthy” digital literacy micro-authentication system. Certification system.

Evidence is the core element to enhance the personalized professional development of kindergarten teachers, therefore, this paper takes evidence-based thinking as the core, blockchain technology as the support, micro-authentication as the main line, and teacher portraits as the carrier to build the micro-authentication system. The architecture of the blockchain-based digital literacy micro-certification system for Chinese teachers is divided into a multimodal resource presentation layer, a data management layer, an online learning input analysis layer, and a visualization display layer.

The multimodal resource presentation layer of the microcertification system contains multimodal learning resources developed by various kindergarten teachers' personalized professional development microcertification specifications, specifically including videos of lectures by famous teachers, typical teaching cases, excellent students' works, virtual simulation experiments, etc. The learning data management layer is used to collect, store, and analyze online learning inputs and visualization display layer.

The learning data management layer is a key layer used to collect, store, and process teachers' learning data. In this layer, data collection and processing are key. Facing a large amount of multi-source heterogeneous data generated in the process of teacher training requires a series of operations such as data cleaning, integration and conversion.

Online learning input analysis has a positive impact on online learning performance and has now become one of the main ways to measure online learning quality. Behavioral input, cognitive input, emotional input and social input are important parts of online learning input. The system intelligently analyzes kindergarten teachers' online learning engagement based on these four dimensions.

The visualization display layer is shown in Figure 4.

The principle of the micro-certificate authentication and display blockchain lies in the fact that the hash value of the previous block is covered in each block, which is strung together into a chain table. Each learner's certificate data is saved in the form of a copy on the blockchain, and the smart contract deployed on the blockchain is able to set business logic such as triggers and conditions, so that any delusional attempt to tamper with or attack the blockchain data requires strong arithmetic power, which is almost impossible to happen.

The education department or organization can determine with kindergarten teachers in a smart contract the achievement goals and number of outcomes that need to be met in order to obtain a training certificate. The smart contract, as a computer language automatic execution program, can automatically store learning certificates on the blockchain, and users can directly access the database to query the micro-certificates through the port, realizing the traceability and tamper-proofing of the certificates.

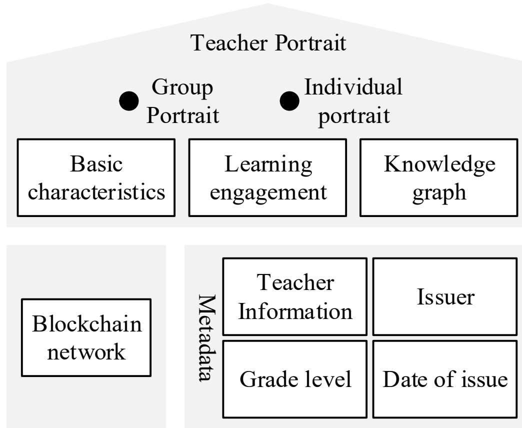

Figure 4: Visual presentation layer

IV. Analysis of individualized professional development for teachers in microcredentialing projects

IV. A. Testing of micro-authentication systems based on blockchain technology

Experimental platform setup:

The experimental environment setup for this paper is shown in Table 1.

Table 1: Experimental environment Settings of this article

Hardware and software	Configuring
CPU	Intel(R) Xeon(R) CPU E5-2678 v3 @ 2.50GHz
GPU	NVIDIA GeForce RTX 2080 Ti
Operating environment	Ubuntu20.01
Memory	8GB
Development environment	Python 3.9 Pycharm CUDA 11.3

Two training models were used: ① MLP, a simple multilayer perceptron with 2 hidden layers, each with 200 units activated using ReLU. ② CNN, a CNN with two 5×5 convolutional layers, a fully connected layer with 512 units and ReLU activation, and a final softmax output layer.

Datasets: in real life, it is difficult to obtain real datasets due to legal and privacy protection limitations, so public datasets commonly used in the field of federated learning are used to test the performance of the model. In this paper, MNIST dataset and CIFAR-10 dataset are used to test the accuracy of image classification.

Experimental results: ① Communication overhead

The number of users n is set to 3, 5 and 10, and 500 rounds are iterated for these three algorithms. The average communication overhead (M) per round for different methods and different number of users is shown in Table 2 to find the average communication per round.

It can be seen that the communication per round of the decentralized federated learning model based on differential privacy is greater than that of the DFL algorithm and FedAVG algorithm. Secondly, the communication volume of these three methods at n=10 is significantly higher than that at n=3. When the number of users becomes larger, more users participate in the federated learning training process in each round, and more information is interacted with, so the communication volume of all three methods becomes larger. For the decentralized federated learning model based on differential privacy, the participants exchange the gradient information after adding noise with each other, and the average communication volume per round is much higher than the other two methods.

Table 2: Average communication overhead per rotation (m)

Methods	FedAVG			DFL			DFL-DP		
	n=3	n=5	n=10	n=3	n=5	n=10	n=3	n=5	n=10
MLP MNIST	1.13	2.25	3.14	2.07	8.46	11.23	5.63	20.42	23.57
CNN CIFAR-10	1.72	3.08	3.67	2.53	10.52	15.76	6.89	21.36	28.04

② Time consumption analysis

The FedAVG algorithm, DFL algorithm and decentralized federated learning model based on differential privacy are iterated for 500 rounds to find the average running time per round.

The average time consumption (s) per round for different methods and different number of users is shown in Table 3.

Comparing n=3, 5, and 10, the training process of users is synchronized in parallel during the federated learning process. In a good communication environment, increasing the number of participants only increases the time of aggregating gradients in the federation server, which is negligible relative to the training time of the local model, so increasing the number of participants does not affect the overall running time of each round.

When n=10, for the MLP MNIST dataset, the running time of the decentralized federated learning model based on differential privacy is higher than the other two algorithms by about 0.19s~0.22s per round. For the CNN CIFAR-10 dataset, the running time of the decentralized federated learning model based on differential privacy is higher than the other two algorithms by about 0.32s~0.36s per round. It can be seen that the average time consumption per round of the decentralized federated learning model based on differential privacy is higher than the other two methods.

Table 3: Average time consumption per rotation (s)

Methods	FedAVG			DFL			DFL-DP		
	n=3	n=5	n=10	n=3	n=5	n=10	n=3	n=5	n=10
MLP MNIST	2.12	2.58	2.04	2.11	2.04	2.01	2.26	2.15	2.23
CNN CIFAR-10	2.63	2.32	2.15	2.27	2.20	2.19	2.57	2.53	2.51

IV. B. Effectiveness of individualized professional development for kindergarten teachers

In this paper, two kindergartens in a city were used as a testing ground for a two-year "personalized professional development training for teachers under the micro-credentialing program", and a quasi-experimental methodology was used to measure and analyze the changes in teacher development before and after the implementation of the program.

The study analyzed the effects of the program on teacher transformation and professional competence through pre- and post-measurement of teacher questionnaires and semi-structured pedagogical interviews.

The "Individualized Professional Development of Teachers under the Microcertification Program" was implemented in two kindergartens in the city between 2022 and 2024. A total of 128 valid teacher development questionnaires, including 60 pre-test and 68 post-test questionnaires, were collected before and after the classroom training.

In order to facilitate data collection and analysis, the questionnaire entries were designed in the form of a five-point Likert scale, and it was planned to analyze the results of the survey in terms of teacher knowledge, teacher skills and competencies, teacher attitudes and beliefs, teacher educational philosophy, and teacher personalized teaching style to illustrate the practical effects of the model.

In SPSS software, these four dimensions were simplified as knowledge, competence, attitude, philosophy and personalization. The paired sample correlations are shown in Table 4. The table shows the paired t-test correlation coefficients between the four dimensions of teacher professionalism and the overall effect before and after the implementation of the lesson study model. Among them, the correlation coefficient of the teacher knowledge dimension before and after the training is 0.055, and its corresponding significance is 0.672. Since 0.672>0.05, the correlation of the teacher knowledge dimension before and after the training is not significant. The pre- and post-test correlations for the other dimensions and the overall effectiveness dimension were also not significant.

Table 4: Pairing sample correlation

Serial number	Matching dimension	Correlation	Significance
①Knowledge	Premeasurement &Afterknowledge	0.055	0.672
②Ability	Premeasurement &Afterknowledge	0.105	0.512
③Attitude	Premeasurement &Afterknowledge	0.035	0.893
④Idea	Premeasurement &Afterknowledge	0.067	0.724

⑤Personalization	Premeasurement &Afterknowledge	0.091	0.410
⑥Overall effect	Premeasurement &Afterknowledge	0.064	0.556

The paired samples test is shown in Table 5. The table shows the results of the paired samples t-test for the five dimensions of teachers' professional development level before and after the lesson study as well as the overall effect of the lesson study. Its various data characterization values include the mean, standard deviation, standard error of the mean, 95% confidence interval of the difference, value of t-test, degree of freedom and two-sided Sig (two-tailed) probability value of each dimension of teacher development.

The data showed that the Sig values of the t-test results of the four dimensions of teacher development before and after the classroom training were 0.000, which were less than the 0.05 level of significance, and the mean scores of the dimensions after combining the classroom training were higher than the results of the pre-test. Therefore, it is concluded that the micro-certification program (personalized professional development for kindergarten teachers) training model constructed with the support of blockchain technology has a significant contribution to improving the professional level of kindergarten teachers in the five dimensions.

Similarly, the t-test Sig value of the overall effect of the kindergarten teacher development survey after the micro-certification program training is 0.000, which is less than the 0.05 level of significance, and its overall score is higher than that before the training. Therefore, it can be determined that the micro-certification program (personalized professional development of kindergarten teachers) constructed with the support of blockchain technology has a significant effect on improving kindergarten teachers, personalized professional development, and overall professional level.

Table 5: Matched sample

	Matching dimension	Pair difference					t	Freedom	Sig.
		Mean value	SD	Standard error of the mean	Difference 95% confidence interval				
					Lower limit	Upper limit			
①	P&A	-1.358	0.669	0.085	-1.425	-0.985	-18.536	70	0.000
②	P&A	-1.413	0.425	0.071	-1.494	-0.933	-20.454	70	0.000
③	P&A	-1.526	0.882	0.092	-1.553	-0.996	-13.526	70	0.000
④	P&A	-1.401	0.694	0.063	-1.427	-0.831	-17.831	70	0.000
⑤	P&A	-1.235	0.721	0.055	-1.286	-0.814	-18.606	70	0.000
⑥	P&A	-1.338	0.509	0.053	-1.335	-0.968	-19.115	70	0.000

V. Conclusion

By constructing a micro-certification system based on blockchain technology, the personalized professional development of kindergarten teachers has achieved remarkable results. The system test shows that under the condition of 10 users' participation, the communication overhead of CNN CIFAR-10 dataset is 28.04M, which is increased compared with the traditional method but still within the acceptable range. The introduction of differential privacy protection mechanism makes the system guarantee data security while controlling the time consumption increase in a reasonable interval of 0.32-0.36 seconds.

The results of the empirical validation show that after two academic years of training practice, all dimensions of teachers' professional development have realized significant improvement. In the paired-sample test, the correlation coefficient before and after the training in the knowledge dimension is 0.055, indicating that teachers have made a substantial breakthrough in knowledge acquisition. What's more, the Sig value of the T-test results of the five professional development dimensions reached 0.000, which is much lower than the significance level of 0.05, fully proving that the micro-certification system has positively promoted the professional development of teachers.

The micro-certification system has successfully cracked the problems of insufficient personalization and imperfect certification system in traditional teacher training. Through the decomposition and reconstruction of competencies, the system provides a customized development path for each teacher, realizing a fundamental shift from standardized training to personalized development. The application of blockchain technology ensures the credibility and traceability of the certification results, providing a reliable digital credential for teachers' professional development. The use of federated learning algorithms not only protects teachers' privacy, but also realizes the effective sharing of learning resources, laying a technical foundation for building an open and collaborative teacher education ecosystem. In the future, the performance of the algorithm should be further optimized and the application scope of the system should be expanded to provide support for the personalized professional development of more teachers.

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