Connotations, Issues, and Strategies of Digital Literacy Assessment for Digitally Empowered Chinese Teachers

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Abstract

From the perspective of digital empowerment, this study attempts to construct a digital literacy evaluation model for Chinese teachers consisting of data collection and storage, processing and mining, and feedback and application of results, with a view to providing strategic references to the problems of Chinese teachers' digital literacy evaluation. The improvement of teachers' digital literacy is the core key to the change of parenting style and the development of education quality in the digital era, but the complexity of Chinese teachers' digital literacy and the limitation of evaluation means lead to the problems of thin data, one-sided results, and high evaluation difficulty. The integration of digital technology provides new ideas to solve the above problems, in which big data can analyse the implicit nature of teachers' digital literacy, blockchain can optimise the storage and management of data to achieve sharing and improve the credibility, and the generative mechanism of generative artificial intelligence enriches the intelligent feedback and application of the evaluation results, and the fusion of the three together promotes the transformation of China's teacher's digital literacy evaluation from empirical decision-making to digital empowerment.

Keywords: Digitalization; Chinese Teachers' Digital Literacy Assessment; Connotations; Strategies

1. Introduction

The term digital literacy was first coined in 1994 by Israeli scholar Yoram Eshet Alkala, and then systematically introduced in 1997 by Paul Gilster in his book Digital Literacy, which describes digital literacy as the use and understanding of information in the digital age, and emphasizes digital technology as a "fundamental life skill" that is "essential to life ". Digital literacy is not a simple skill or ability, but an important, composite, interdisciplinary ability that

concerns the basic life of all people (Li & Du, 2025), and many countries and regions have deeply recognized the importance of digital talents for today's era, and the European Union made digital literacy one of the eight core literacies for all people as early as 2005. In the field of education, A number of countries have long been intensively engaged in research on the evaluation of digital literacy for this particular group of teachers, and some international organizations and countries have put forward frameworks or standards on teachers' digital literacy; In 2021, China promulgated the Action Program for Enhancing Digital Literacy and Skills of All People, which proposed to "continuously improve teachers' awareness and ability to use digital technology to improve education and teaching", and released the education industry standard of "Teachers' Digital Literacy" at the end of 2022, which profoundly reflected that enhancing teachers' digital literacy is the core key to the implementation of the national strategy of digital transformation of education, and also provided directional guidance and instrumental support for the cultivation and evaluation of teachers' digital literacy(Wu & Chen, 2023). Enhancing the digital literacy of Chinese teachers is very important to the transformation of parenting and the development of high-quality education, and is the core soft power to promote the digital transformation of China's education, as well as helping to cultivate high-quality talents and build a high-quality education system.

The current evaluation of Chinese teachers' digital literacy has many problems such as relying on subjective judgement and insufficient data coverage(Liu & Yin, 2024), how to effectively measure teachers' digital literacy has to be further practiced and explored. The digital era has led to the transformation of educational evaluation from the previous experience-led to digital empowerment, and the acquisition of assessment data has expanded from the previous focus on results to focus on results, processes and other aspects, so as to more scientifically promote the evaluation of Chinese teachers' digital literacy in the direction of accurate, dynamic and sustainable development. However, it must also be seen that digitally empowered teachers' digital literacy evaluation will bring problems such as massive and redundant data, unsynchronized assessment of multiple subjects, data security risks and data distortion, etc. In response to the above problems, blockchain's technology of decentralization, distributed storage, data encryption, etc., can be effectively responded to, and generative artificial intelligence can be enriched with intelligent feedback and application of the evaluation results based on big data and blockchain technology, deepening the diagnosis and application of education evaluation, and improving the quality of the evaluation process. application, and deepen the functions of diagnosis, appraisal, improvement and incentive of education evaluation.Xi Jinping emphasized the need to accelerate the in-depth integration of cutting-edge information technologies such as big data, blockchain and artificial intelligence, and to promote integrated innovation and fusion applications (Xi, 2109). Based on this, exploring the in-depth integration of "big data + blockchain + generative artificial intelligence" technology can be used as a powerful tool to solve the problem of China's teachers' digital literacy evaluation. This study aims to clarify the connotation and issues of Chinese teachers' digital literacy evaluation, analyze the opportunities brought by big data, blockchain and generative artificial intelligence technologies to solve the problems of Chinese teachers' digital literacy evaluation, and propose effective strategies to digitally empower China's teachers' digital

literacy evaluation, so as to realize accurate and effective evaluation of China's teachers' digital literacy, and help to improve China's teachers' digital literacy and education quality.

2. The Connotation and Methods of Teachers' Digital Literacy Evaluation

2.1. Connotation of Teachers' Digital Literacy Evaluation

Teachers' digital literacy is the awareness, ability and responsibility of teachers to appropriately use digital technology to acquire, process, use, manage and evaluate digital information and resources, to discover, analyse and solve educational and teaching problems, and to optimise, innovate and change educational and teaching activities (Ministry of Education, 2022). Teachers' digital literacy evaluation, on the other hand, is a process of promoting teachers' own professional development and enhancing students' digital literacy for the purpose of using feasible scientific means, systematically collecting information, analysing and interpreting it, and making value judgments on teachers' digital education phenomena, so as to continuously improve teachers' digital literacy or provide evidence for decision-making. Teachers' digital literacy evaluation is the key to test the landing of teachers' digital literacy, which is of great significance to the change of parenting style and the high-quality development of education: firstly, the results of the assessment reflect the deficiencies in teachers' digital literacy and provide data basis for targeted policy-making; secondly, the evaluation practice of teachers' digital literacy can boost the construction and development of theories related to teachers' digital literacy; At the same time, the results of teachers' digital literacy evaluation dynamically reflect the effectiveness of education reform, and can provide suggestions and direction guidance for subsequent reforms; finally, it can help teachers, schools and even the society to comprehensively improve their digital literacy, so as to jointly build a digital China.

2.2. Teachers' Digital Literacy Evaluation Methods

At present, countries around the world can reach a framework consensus to a certain extent on digital literacy evaluation, but the specific assessment tools and measurement indicators have not yet formed a unified standard (Wang, 2023). Regarding the evaluation of digital literacy of the teacher group is still in the emerging stage in China, from the existing research results, combined with the different external performance of teachers can be categorised into the following three ways of evaluating teachers' digital literacy: first, standardised tests, the results of teachers' answers to pre-set test questions as the evaluation of their digital literacy level, for example, Russia refers to the European Digital Competence Framework (European Digital Competence Framework 2.0), which is a standardised test. Digital Competence Framework (European Digital Competence Framework 2.0), for example, the Russian teachers' digital literacy online assessment tool, which can assist teachers in self-assessment of digital literacy, and generate corresponding capacity enhancement suggestions based on the assessment results, to meet the teachers' personalised digital literacy enhancement needs (Du & Tang, 2022); Secondly, questionnaire-based self-assessment, by drawing on the analysis to build a targeted evaluation index system of teachers' digital literacy, for example, Yang Shuang et al. integrated the existing research results for the characteristics of college teachers' work to build a questionnaire of 5 dimensions, 18

evaluation indicators of the evaluation of digital literacy of college teachers, the collection of the questionnaire data for the analysis of the degree of reliability and validity, and the verification of the results show that it has a certain degree of reasonableness (Yang ＆Zhou, 2019); third is the behavioural performance assessment, through the collection of teachers in the process of the specific teaching situation data and expressive data analysis to obtain their digital literacy level. For example, in 2017, the European Union developed a "teaching self-assessment tool" that can be used for teachers to assess their own development of digital literacy, and in the same year, Spain also developed a tool to support the self-assessment of teachers' digital literacy, in which teachers upload their own digital literacy-related awards, teaching achievements and other materials as an effective basis Teachers upload their own digital literacy-related awards, teaching achievements and other materials as an effective basis for evaluation to obtain the certification of teachers' digital literacy level Teachers upload their own digital literacy-related awards, teaching achievements and other materials as an effective basis for evaluation to obtain the certification of teachers' digital literacy level for evaluation to obtain the certification of teachers' digital literacy level (INTEF,2020).

3. The Reality Issues of Chinese Teachers' Digital Literacy Evaluation

Teachers' digital literacy has complex, comprehensive and high-level attributes, coupled with the limitations of its assessment methods, making the evaluation of teachers' digital literacy has problems such as thin data, one-sided results, and great difficulty in assessment, which restricts the quality and effectiveness of the evaluation of teachers' digital literacy.

3.1. Problems Inherent in The Evaluation of Chinese Teachers' Digital Literacy

The comprehensive, implicit, contextual and dynamic nature of teachers' digital literacy determines its composite and higher-order competence, which also poses a challenge to the accurate evaluation of teachers' digital literacy.

3.1.1. The Comprehensive Nature of Teachers' Digital Literacy

Teachers' digital literacy is a conceptual category related to digital literacy based on teachers' roles, which is beyond the general category of knowledge and competence, and is a synthesis of teachers' cognition, behaviour, emotion and will in the process of education and teaching. The release of the Digital Literacy for Teachers provides a specific evaluation framework model for the evaluation of teachers' digital literacy, which has an important function of guiding the direction and interpreting the comprehensive characteristics of teachers' digital literacy. However, in the specific practice of teachers' digital literacy assessment, such and such problems inevitably arise, such as difficulties in fully grasping the comprehensive characteristics of generalisation, overly detailed indicators, or stealing concepts, etc. These problems affect the effectiveness of teachers' digital literacy assessment.

3.1.2. The Hidden Nature of Teachers' Digital Literacy

At present, the assessment of teachers' digital literacy is still based on standardised tests, questionnaires or interviews, and behavioural performance such as typical events or achievements,

but elements such as teachers' digital awareness, competence, and values are implicit, making it difficult to accurately characterise and assess them. Process data of teachers' teaching can be used indirectly as evidence to reflect the relevant implicit digital literacy, but the two are not linearly related, so how to rely on process data to obtain reliable evidence to accurately evaluate teachers' digital literacy has yet to be studied in depth.

3.1.3. Contextualisation of Teachers' Digital Literacy

Teachers' digital literacy is the comprehensive literacy of teachers who use digital information and resources to produce educational behaviours in specific educational and teaching contexts, and specific contexts are the carrier of all educational and teaching activities. Focusing on the real educational and teaching context is an important factor to consider in the assessment of teachers' digital literacy, and the scientific and appropriate context of the assessment will directly affect the effectiveness of the results. In other words, the design of assessment questions needs to fully consider the reliability and validity of the assessment results in the corresponding context. Simply examining teachers' written mastery of digital knowledge or digital skills is difficult to fully portray teachers' digital literacy, and an assessment of teachers' digital literacy divorced from its context cannot guarantee the authenticity of its results.

3.1.4. Dynamics of Teachers' Digital Literacy

Teachers' digital literacy will change dynamically due to the development of the subject, environmental changes, professional training, etc. Therefore, external incentives, guidance, etc., will promote the improvement of teachers' digital literacy. The current Chinese teacher literacy assessment data collection is mostly outcome data(Hu et al., 2023), and the focus on evaluation results has neglected the releasability of the results and the guiding role of subsequent interventions, resulting in the assessment results failing to provide guidance for the improvement of teachers' digital literacy and professional development, and losing the functional value of the evaluation itself.

3.2. External Problems of Teachers' Digital Literacy Assessment

The intrinsic characteristics of teachers' digital literacy bring certain challenges to assessment, but there are also practical problems such as the assessment framework needs to be specific, the assessment method needs to be explored, and the main body of assessment needs to be diversified, which are limitations that make it difficult for Chinese teachers' digital literacy assessment to take hold.

3.2.1. Assessment Framework to be Specific

How to correspond the implicit characteristics of teachers' digital literacy with specific operational framework indicators is crucial, coupled with the complexity of teachers' digital literacy makes the overall construction of the framework indicators even more difficult, the Ministry of Education of China issued the "Teachers' Digital Literacy" standard clearly divided into 5 first-level dimensions, 13 second-level dimensions and 33 third-level dimensions, but how to connect the framework dimensions with teacher behaviour in practice, still needs to be further specified.

3.2.2. Assessment Methods to be Explored

The three typical ways of assessing Chinese teachers' digital literacy are not mature: standardised tests are fixed and one-sided, making it difficult to assess the comprehensive performance of teachers' digital literacy, especially the true reflection of inner consciousness, emotions, values and other traits; questionnaire-based self-assessment is subjective, and the subjective thinking of individual teachers or differences in their grasp of the standards will affect the assessment results with errors; and the behavioural assessment, although it takes into account the internal characteristics of teachers' digital literacy, is still to be specified. Although the implicit and situational characteristics of teachers' digital literacy are taken into account, there are also the problems of whether the assessment data are real, whether the assessment indexes are operable, and whether the assessment costs are controllable. Therefore, the evaluation of teachers' digital literacy needs to be further explored.

3.2.3. Subjects of Assessment Need to be Diversified

At present, the main body of Chinese teachers' digital literacy assessment is mainly composed of school administrators or researchers, and the professionalism of the main body of the assessment will directly affect the scientific and effective results of the assessment. If the main body of the assessment is not sufficiently educated, or has a one-sided understanding of the assessment objectives, the results of the assessment will lose their value, and it will not be possible to grasp the level of teachers' digital literacy scientifically, objectively and truthfully. Therefore, enriching the subjects of teachers' digital literacy assessment and including multiple subjects such as society, schools, parents, students and teachers in the assessment will obviously be more credible and effective.

4. The Technical Tools of the Digital Era: Big Data + Blockchain + Generative Artificial Intelligence

The development of technology brings great energy to educational change, and also provides new perspectives and opportunities for cracking the problem of Chinese teachers' digital literacy evaluation: big data builds a more diversified, scientific and objective data base, blockchain assists in the storage and management of big data, and generative artificial intelligence continuously enriches the intelligent feedback and application of evaluation results. The deep integration between the three is a feasible way to break through the dilemma of teachers' digital literacy evaluation.

4.1. Big Data

Big data has penetrated into every aspect of the education field, becoming an important evidence for educators to make scientific decisions and deploy actions, and also empowering and increasing the effectiveness of educational change. Big data has the potential to tap into the hidden characteristics of teachers' digital literacy, as well as to focus on the comprehensiveness, objectivity and specificity of teachers' digital literacy development, which not only helps to

understand teachers' professionalism and development at a deeper level, but also builds a new ecology for the evaluation and development of teachers' digital literacy.

4.1.1. Big Data Broadens The Multidimensionality of Teachers' Digital Literacy Data Collection

Big data has the characteristics of huge data scale, high speed of data processing, huge data value, and diverse data types, which accelerates the transformation of educational evaluation from empirical judgement to digital empowerment, and some non-explicit and non-intuitive qualities of teachers' digital literacy can be tracked and measured with the help of relative data records and analyses. Nowadays, researchers have conducted preliminary exploration of digital literacy assessment based on big data: Wang Qiong et al. quantified learners' reflective consciousness based on peer online learning mutual assessment data (Wang et al., 2019), and Wang Yang et al. obtained the results of learners' input state based on physiological, learning and other behavioural data analysis (Wang et al., 2019). Based on this, big data can provide effective evidence for the assessment of digital literacy, to achieve a more accurate quantitative characterisation, from "implicit" to "evidence-based".

4.1.2. Big Data Improves the Scientificity of the Evaluation Index of Teachers' Digital Literacy

The Digital Literacy of Teachers standard puts forward a framework model of Chinese teachers' digital literacy, while the specific behavioural indicators corresponding to each dimension have yet to be explored and perfected. Text analysis or the Delphi method can improve the indicators, but they are subjective, and big data can make up for this kind of defect. Big data can be analysed by pre-processing the data to be mined, such as cleaning, integrating, transforming, and statute, and then analysing the connections between the data. Therefore, by pre-processing and mining the collected data of teachers' digital literacy evaluation and refining and perfecting the specific indicators under the assessment framework, the scientific and developmental nature of teachers' digital literacy evaluation indicators can be achieved.

4.1.3. Big Data Ensures the Objectivity of Teachers' Digital Literacy Evaluation Results

Digital empowerment of teachers' digital literacy evaluation returns to the real process of teacher education and teaching, focusing on the reality and context of the data. Unlike previous methods such as questionnaires and observations, digitally-enabled teacher digital literacy evaluation can achieve multi-dimensional and all-round recording of text, images, audio-video, physiological behaviours, basic information, and other digital literacy-related education and teaching data, reducing the involvement of personal subjective colours and the constraints of single data type and insufficient quantity, and improving the objectivity of teacher digital literacy evaluation.

4.2. Blockchain

Big data improves the comprehensiveness, science and objectivity of teachers' digital literacy data to empower evaluation, but there are also problems such as cumbersome data collation, low timeliness of information sharing, and easy tampering of data information. Blockchain technology

can precisely solve the above problems, blockchain technology is a kind of common maintenance by multiple parties, the use of cryptography to ensure the security of transmission and access, can achieve consistent storage of data, difficult to tamper with, to prevent repudiation of the bookkeeping technology, also known as distributed ledger technology (China Academy of Information, 2019). Blockchain uses "block-chain" as the structure to store data, and uses a trusted consensus mechanism to synchronise data changes (Lan et al., 2021), so it can prevent information tampering and forgery, thus increasing data security. The consensus mechanism, decentralisation, high degree of encryption and other technical support of blockchain technology can effectively assist in the storage and management of big data, and help the evaluation results to be comprehensive, objective and credible.

4.2.1. "Consensus Mechanism" Enhances Data Sharing

As a distributed ledger, blockchain can guarantee that data are shared by all members, realise network docking between points, and provide technical support for data co-construction, sharing and communication among school administrators, teachers, students, parents and other multiple subjects. Multiple subjects can upload data and view teachers' teaching situation at any time, parents can understand the teaching situation of school teachers at any time, and teachers can obtain parents' feedback in time, realising in-depth communication between home and school. The consensus mechanism of the blockchain can enhance the viscosity between multiple subjects and facilitate the evaluation subjects to jointly participate in the whole process and supervise and intervene in the development of teachers' digital literacy.

4.2.2. "Decentralised" and convenient data management

The data on the blockchain are backed up by each other between nodes, and there is no central control to achieve data transmission and update without relying on a third party (Yang et al., 2017). In the digitally empowered teachers' digital literacy evaluation, blockchain automatically generates timestamps to time-tag the data, and can record the data of teachers in different scenarios such as office, classroom, etc. based on the chronological order, and its decentralised feature can assist managers to collaborate with different platforms or systems to record the behavioural data, thus reducing the cumbersome nature of sorting out the data of different scenarios.

4.2.3. "Highly Encrypted" to Ensure Data Security

Blockchain's asymmetric encryption algorithm can encrypt and decrypt the data using public and private keys in pairs, with the public key facing all users on the blockchain to ensure transparency, and the private key facing only the owner to reduce the risk of tampering with the data, thus ensuring the security of the data (Zheng & Yang, 2020) and making the evaluation results more objective.

4.3. Generative Artificial Intelligence

Generative AI is based on algorithms, models, rules and other components that learn objects from massive data and then generate original content. The Measures for the Administration of Generative AI Services (Exposure Draft) states that the state encourages the priority adoption of

safe and trustworthy software, tools, computing and data resources (State Net Information Office., 2023). Generative artificial intelligence "accurate understanding of instructions + innovative content synthesis + human preference data output" technology combination favoured by many fields, but its internal structure and the opacity of the decision-making process is difficult to provide the basic logic of the operation of the large model, this technology "black box" leads to hidden output results. This technical "black box" leads to hidden dangers or bias in the output results, including over-collection of data, leakage, falsification, bias and other problems that may occur in the process of processing data, and is therefore questioned by users. As mentioned in the previous section, big data and blockchain can exactly effectively deal with the above problems, thus guaranteeing the application of generative AI in the field of education.

4.3.1. Generative Pre-Training Model Promotes the Immediacy of Feedback for Teachers' Digital Literacy Evaluation

Generative pre-training model is to train unsupervised autonomous learning on the given data text or contextual information identified in multiple rounds of dialogue in advance, so as to build a dialogue algorithm model that accurately understands instructions and generates feedback. In the evaluation of teachers' digital literacy, generative AI can accurately understand the instructions and give targeted and immediate evaluation and feedback by analysing the lesson plans, teaching methods and exchanges of opinions during the teaching process, as well as objectively evaluating teachers' works or answers, and also intelligently analysing high-order and composite data processed by big data and blockchain to obtain the level of teachers' digital literacy and to form an analysis text for teachers' digital literacy. form an analysis text to give intelligent guidance for teachers' digital applications.

4.3.2. Neural Network-Based Language Model to Generate Personalised and Accurate Portraits of Teachers' Digital Literacy

Generative Artificial Intelligence (AI) simulates human brain functions to achieve deep learning and build a new picture to promote the improvement of teachers' digital literacy. Embedding the human brain decision-making of teachers' digital literacy evaluation in the big language model of generative AI, mining data to complete complex logical reasoning and automatically constructing features to generate an accurate portrait model of teachers' digital literacy, and establishing personalised and dynamic growth profiles of teachers' digital literacy, as well as establishing a personalised and accurate profile of teachers. Digital literacy personalised dynamic growth files, more comprehensively record the changes and development of teachers' digital literacy, and empower the value-added evaluation of teachers' digital literacy.

4.3.3. Human Feedback Reinforcement Learning (RLHF) for Teacher Development Evaluation

The RLHF technique first selects a suitable pre-trained language model and obtains an optimised preliminary text model through unsupervised autonomous training; secondly, it constructs a reward model, manually sorts and labels the results generated in the previous stage, trains the reward function model, and strengthens the automated evaluation of the model outputs; then it uses reinforcement learning for fine-tuning, and utilises a proximal optimisation policy

(PPO) algorithm to fine-tune the pre-trained language models for fine-tuning, and ultimately generating text that meets human expectations. Generative AI can construct targeted teacher digital literacy scales according to the evaluator's evaluation goals and object characteristics, realise individual teacher digital literacy assessment based on multimodal data analysis evidence, and integrate "evaluation" and "development". Based on the assessment results, we analyse the contents and methods of various scenarios of teachers' teaching, provide guidance suggestions and specific knowledge-based text resources for teachers' digital literacy enhancement, and improve the digital level of teaching and learning to enhance teachers' digital literacy.

5. Response Strategies for Teachers' Digital Literacy Evaluation in China

The integration of "Big Data + Blockchain + Generative Artificial Intelligence" technology is a technological tool to solve the problem of Chinese teachers' digital literacy evaluation in the digital era. This study tries to construct the evaluation model of Chinese teachers' digital literacy based on the perspective of digital empowerment from the perspective of data collection and storage, data processing and mining, and feedback and application of the results.

5.1. Data Collection and Storage

The collection of teachers' digital literacy evaluation data needs to guarantee the comprehensiveness, dynamics and accuracy of the data, which must be able to collect the multimodal data of teachers in different scenarios as well as the operation flow data of multiple subjects. On the basis of guaranteeing the security and credibility of the data, a multimodal data collection strategy is formulated according to the different qualities of the data, so as to realise the collection and storage of data in multiple scenarios, such as school, society and family. Through the "multimodal data collection" and the "chain of teachers' digital literacy alliance chain with collaborative on-chain and off-chain storage", the collection of teachers' digital literacy data is guaranteed to be comprehensive, safe and traceable.

5.1.1. Multimodal Data Collection

Data collection can make use of portable sensing systems, intelligent teaching platforms and other all-round, whole-process collection of teachers' basic, physiological, psychological, teaching and achievement level data. Basic data such as gender, education, profession, age, title, work history, etc. can be acquired from the teacher information management platform; physiological data can be acquired through relevant portable intelligent devices, such as smart bracelets that can capture changes in heart rate and blood pressure, and wearable brain wave detection devices that can capture changes in brain waves; psychological data can be acquired through questionnaires or behavioural recognition, such as the use of a panoramic Psychological data can be obtained through questionnaires or behavioural recognition, such as using panoramic cameras to collect facial and behavioural changes during the teaching process, and analyse teachers' emotions and internal psychological reflections, etc. Teaching data is a direct reflection of the degree of application of teachers' digital teaching knowledge and skills, and devices such as panoramic cameras, smart bracelets, and weblogs can be used as a means to obtain behavioural data; Outcome output data can be obtained from the teaching platform, special materials, etc., such as

the level of digitally related competence, certification, typical cases, and award-winning achievements, etc. The output data can be obtained from the teaching platform and special materials, such as digitalisation-related competence levels, typical cases, award-winning results, etc.

5.1.2. On-Chain and off-Chain Collaborative Data Storage in The Federation Chain

As the huge storage space of multimodal data contradicts with the limited storage space of the blockchain, it is difficult to store all the data in the on-chain storage space, so a large amount of data related to the application scenarios are generally stored in the off-chain. In the process of teachers' digital literacy evaluation, including multiple subjects, data analysis platform, etc. exist in the form of nodes in the teachers' digital literacy alliance chain, if the data are stored in the nodes of the alliance chain, it is necessary to go through the four basic processes of smart contract auditing, data signing, data storage under the chain, and data hashing on the chain:

(1) Smart contract auditing. This procedure is used to audit whether the data operation meets the conditions of data storage and reading, etc., i.e. For example, when a member of the subject of the alliance chain wants to store or modify a certain piece of information, if the subject has not yet met the level requirements set by the smart contract, the alliance chain will autonomously reject the subject's request for information change; (2) Data Signature. The data will be further processed by the alliance chain after the smart contract has been reviewed and approved, and the data is generally signed using asymmetric encryption algorithms such as RSA and ECC to authenticate the sender's identity to make the data non-repudiation and traceability; (3) Off-chain data storage. After completing the data signature, the data can be stored in self-built distributed database clusters according to the storage requirements of different modal data to improve data availability and fault tolerance; (4) Data hashing up the chain. Calculate to obtain the hash value of the file data stored in the database under the chain, and generate the unique fingerprint of the data, when need to use this data under the chain, only need to compare the fingerprint on the chain with the fingerprint under the chain, if the same means that the data has not been modified, if different means that the data has been modified.

5.2. Data Processing and Mining

After data collection and proper storage, it is necessary to carry out data cleaning, multimodal feature fusion and data analysis of "human in the loop" to achieve data processing and mining.

5.2.1. Data Cleaning

In real scenarios, data anomalies, containing noise is the norm, the data cleaning is the missing values, noise data and abnormal data processing, for the missing data can be handled accordingly for its characteristics, such as teaching, basic and other discrete data missing or abnormal can be taken to solve the mean value filling; noise data improperly handled will lead to subsequent data mining, and even affect the generation of models deviating from the actual application. Noise data can be dealt with by cluster analysis, regression method, or directly removed; abnormal data can be manually processed by referring to the neighbouring data or external correlation.

5.2.2. Multimodal Feature Fusion

Joint multimodal data analysis can establish the overall connection of the data (Zhang,Q. & Wu,F.T.,2016), the fusion of multimodal data features is a prerequisite for analysis, and the most representative method is Bimodal DAE (Ngiam J,Khosla A,et al.,2011), which obtains the common qualities of the data through the deep learning of unimodal data, and reconstructs and correlates the qualities of the different modal data on the basis of which the multimodal data are connected to each other to explore the association between the multimodal data. The method is based on deep learning of unimodal data to obtain the common qualities of the data, and on this basis, the qualities of different modal data are reconstructed and correlated, so as to explore the correlation between multimodal data.

5.2.3. Human-in-the-loop Data Analysis

Human-in-the-loop is a method that takes advantage of the fact that humans are better than machines at making comprehensive and fuzzy judgments, combines the human brain with artificial intelligence, and continuously optimises efficiency to improve the accuracy of data prediction (Li et al., 2017). Behavioural data are extracted to explore the relationship between different behavioural data and construct the relationship between behavioural data and teachers' digital literacy dimensions. Afterwards, the results of data mining analysis are used to obtain the characteristics of teachers' digital cognition, competence level, and affective attitudes, so as to explore teachers' digital awareness, knowledge and skills, application, social responsibility, and professional development, and ultimately help generate the results of teachers' digital literacy assessment.

5.3. Feedback and Application of Results

Based on the evaluation results of teachers' digital literacy, a group and personalised accurate portrait of teachers' digital literacy is generated to achieve the evaluation, optimisation and application of teachers' digital literacy.

5.3.1. Generate Accurate Portraits of Teachers' Digital Literacy

Based on the acquisition of all-round massive, rich and safe data resources, generative AI can integrate and differentiate the processing of data information of different space-time, structure and type, and make multi-dimensional, three-dimensional and situational portrayal of teachers' digital literacy, so as to generate accurate portraits of teachers' digital literacy based on the full-sample, visual, dynamic and predictable data. Generative AI can also assist teachers to obtain the shortcomings of their own digital literacy development, understand the reasons for the existence of problems, and provide guidance for the subsequent improvement of teachers' digital literacy and professional development. At the same time, the generated digital literacy portrait of teachers is not a linear presentation of teachers' teaching trajectory, but a three-dimensional, deepened and accurate portrait based on the explicit behavioural trajectory that constantly explores the hidden characteristics and developmental features of teachers' digital literacy, linking external behavioural performance with internal ideological dynamics, characteristics and developmental

trends, and further revealing their internal connections, so as to grasp the developmental law of teachers' digital literacy.

5.3.2. Forming a Management Model Based on Digital Evaluation

Through the generated group and personalised accurate portraits of teachers' digital literacy, we can understand the current status of the digital literacy levels of different types and levels of teacher groups and individuals, and also carry out value-added evaluations by combining the dynamics of the data and other characteristics. Therefore, digitally-enabled evaluation of teachers' digital literacy can provide support for school management's analysis, assessment, prediction and feedback on teachers' digital literacy, provide a detailed understanding of the overall situation of teachers' digital literacy, provide personalised and targeted support initiatives for teachers' digital literacy enhancement, and realise the precision and effectiveness of teachers' digital literacy cultivation and teachers' digital governance, so as to promote the overall professional development of teachers at a deeper level. Professional development.

5.3.3. Deepening the Interaction and Co-Education Mechanism of Multiple Subjects

The digitally-enabled evaluation of teachers' digital literacy has made it possible for multiple subjects to participate in the evaluation, such as school administrators, teachers' self-assessment, peer review, and service users' review, which enhances the sharing and exchange of teachers' digital literacy data among multiple subjects, makes it more convenient to share and enquire about the information among families, schools, and students, and promotes the objectivity, multi-dimensionality, and infinite proximity to the truth of the evaluation results, and also establishes a mechanism for deepening the co-education of multiple subjects. It also builds a good cornerstone for deepening multiple subject co-education. For example, teachers can always reflect and adjust their teaching methods or strategies based on the evaluation feedback from schools, parents and students to promote the occurrence of in-depth digital teaching classrooms; administrators can evaluate each teacher more objectively and fairly and provide corresponding training support according to the shortcomings of the teachers; peers can promote communication and interaction with each other based on the evaluation results to realise the exchange of high-quality resources and experience; parents can also directly interact with each other; and parents can more directly interact with each other to achieve a better quality of education. Parents can also have a more intuitive understanding of what teachers teach and what students learn so that they can better cooperate with the school to achieve co-education.

6. Outlook

This study discusses the feasibility of and strategies for evaluating the digital literacy of Chinese teachers from the perspective of the integration of "big data + blockchain + generative artificial intelligence" technologies, but how to put this idea into practice requires further research and discussion. For example, the evaluation scale of Chinese teachers' digital literacy has yet to be clarified. Teachers at different levels and types of teachers have great differences in digital awareness, emotions, teaching behaviours, etc., and their specific behaviours are also different, so the refinement of the evaluation scale of digital literacy for different levels and types of teachers

can provide a more objective and valuable reference for the evaluation results; as well as the acceleration of the "Big Data + Blockchain + Generative Artificial Intelligence" technology convergence perspective, the feasibility and related strategies. Blockchain + Generative Artificial Intelligence", accelerate the top-level design and development of the technology integration, accelerate the landing and application of the technology, establish a digital literacy growth profile of Chinese teachers oriented to lifelong learning, and realise the objectivity, science, maturity and fairness of the evaluation process, so as to effectively push forward the reform of China's education evaluation.

Author Contributions:

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