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Review

Metaverse Solutions for Educational Evaluation

Lingling Zi † and Xin Cong *,†

College of Computer and Information Science, Chongqing Normal University, Chongqing 401331, China; zll@cqnu.edu.cn

* Correspondence: chongzi610@163.com

† These authors contributed equally to this work.

Abstract: This study aims to give a comprehensive overview of the application of the metaverse in educational evaluation. First, we characterize the metaverse and illustrate how it can support educational evaluation from the perspectives of virtual reality, augmented reality, and blockchain. Then, we outline the metaverse exploration framework and summarize its technical advantages. Based on this, we propose a metaverse-based implementation scheme to address the issues of reliability, accuracy, and credibility in educational evaluation. Finally, we show its implementation difficulties, performance evaluation, and future work. This proposed scheme opens up new research directions for the reform of educational evaluation while expanding the potential and reach of metaverse applications in education. We think that this study can help researchers in building an ecosystem for educational evaluation that is trustworthy, equitable, and legitimate.

Keywords: educational evaluation; metaverse; virtual reality; blockchain; augmented reality

1. Introduction

Educational evaluation plays an important role in deepening the reform of the education system and promoting the modernization of education. Metaverse [1,2], the latest form of the next-generation Internet, offers a fresh chance to change educational evaluation [3,4]. It creates a 3D virtual space with linked perception and shared characteristics that closely integrates the virtual and physical worlds. The virtual space brings up new opportunities for educational evaluation, which makes it take a big step towards modernization and professionalization. However, the application of the metaverse in educational evaluation needs to be investigated in depth in order to effectively fulfill its supporting role.

Metaverse empowers the educational evaluation process and helps improve traditional evaluation methods. The traditional evaluation methods are mainly to selectively extract data according to the prescribed evaluation indicators under unnatural scenarios, and construct an evaluation model for particular issues according to the characteristics of the data [5]. The evaluation model relies heavily on the prior knowledge of experts, and the related data is stored in a central database, which leads to some problems such as reliability, accuracy and credibility. First, evaluation data are usually collected by wearable devices and monitoring devices in specific environments, which makes it difficult to access the real state of learners in natural conditions, thus limiting the reliability of evaluation data [6,7]. Secondly, existing evaluation methods, whether quantitative or qualitative, are more inclined to the evaluation of knowledge and skills, which is inadequate for accurate evaluation of the comprehensive ability of learners [8–10]. Finally, secure access to learners' evaluation data, and assurance that it is not manipulated, have proven to be difficult problems in educational evaluation, and therefore a new mechanism to solve the problem of credibility is urgently needed [11–13].

Metaverse, supported by a variety of advanced technologies, provides possible solutions to the above problems. Among them, virtual reality (VR) creates a virtual environment that allows learners to immerse and perceive in multiple dimensions, while augmented

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Citation: Zi, L.; Cong, X. Metaverse Solutions for Educational Evaluation. *Electronics* **2024**, *13*, 1017. https://doi.org/10.3390/electronics13061017

Academic Editors: Dongsik Jo, Kangsoo Kim, Myungho Lee, Gun Lee and Hanhoon Park

Received: 3 February 2024
Revised: 25 February 2024
Accepted: 4 March 2024
Published: 8 March 2024

reality (AR) increases learners' perception of the physical world with information obtained through computer vision methods. VR/AR technologies have positive cognitive and pedagogical benefits in education [14], such as assisting 3D vector learning [15], enhancing engineering competency literacy [16], and improving the learning experience. With their help, deeply immersive evaluation scenarios [17–19] can be constructed in the metaverse. This lays the foundation for the acquisition of evaluation data and the implementation of evaluation methods. Furthermore, the blockchain is considered a breakthrough technology in terms of security and trustworthiness [20,21]. Using this technology to build a trust system can guarantee security and credibility of evaluation data. At present, the development of the metaverse is still in the primary stage, and there is no mature metaverse construction framework in the field of educational evaluation. In view of the important roles of the technologies mentioned, this paper explores the application of the metaverse in educational evaluation from VR, AR, and blockchain perspectives.

The main contributions of this paper are as follows. (1) We present a metaverse exploration framework and summarize the current state of research within this framework, providing a stepping stone for the metaverse application in educational evaluation, as well as a reference for reforming the evaluation model. (2) We attempt to put forth a metaverse-based implementation scheme for educational evaluation, and elaborate on it from three perspectives: data acquisition, data analysis and processing, and data display and storage. Also, we give practical guides, highlight difficulties, and suggest methods for evaluating the implementation of this scheme. This scheme broadens the possibility and scope of application, while offering new research avenues for scholars. (3) We draw a series of research challenges and opportunities from a review of techniques and applications, and hope to help researchers, engineers, and educators establish a reliable, fair, and credible ecosystem for educational evaluation.

The rest of the paper is structured as follows. Section 2 provides a brief overview of the metaverse and on this basis, Section 3 summarizes a metaverse exploration framework. Then, Section 4 demonstrates a metaverse-based implementation scheme, and Section 5 shows implementation difficulties and performance evaluation. Finally, Section 6 suggests future work, and Section 7 concludes the paper.

2. Metaverse

This section presents the metaverse, its characteristics, and an analysis of its technical feasibility for educational evaluation. On this basis, we discuss the supporting role of the metaverse from the perspective of VR, AR, and blockchain.

2.1. The Characteristics of Metaverse

The concept of the metaverse was proposed in the novel "Snow Crash" in 1992, marking the beginning of the metaverse era. Subsequently, the emergence of popular games such as "Roblox" and "PokemonGo", as well as the release of NFT, accelerated the development of the metaverse. In recent years, it has attracted extensive attention from researchers for its characteristics, such as 3D online digital space combining virtual and physical worlds, immersive user experience, and new economic and social civilization systems [22,23]. The above characteristics provide technical feasibility for implementing educational evaluation reform, which is reflected in the following three aspects.

- Integration of reality and the imaginary. The metaverse can create scenarios that not only mimic the characteristics of the actual world, but also go beyond their geographical bounds and physical constraints [24]. This can be used while creating evaluation scenarios. In the evaluation scenarios, a lot of learners' data, such as behavioral, characteristic, and psychological data, can be captured using VR or AR devices. The data acquired can also be secured using blockchain technology. Therefore, integration of reality and the imaginary offers a practical means of acquiring reliable evaluation data.

- Multi-dimensional interaction. The metaverse supports multi-dimensional interaction methods such as virtual agent interaction, multi-sensory interaction, and multi-scene interaction, which can be adopted in the process of evaluation activities, enabling learners, evaluators, and the evaluation scenarios to interact and communicate in a real and natural way [25,26]. On the one hand, it encourages more evaluators to participate in the evolutional activities; on the other hand, it enriches the evaluation content and expands the evaluation methods. The above can evaluate learners more comprehensively and provide a feasible means for accurate evaluation.
- Trusted mechanism. The development and operation of the metaverse follows the rules supported by blockchain technology, and one of the advantages of blockchain technology is the level of trust in its mechanism [27,28]. A trusted mechanism is very important in educational evaluation and can be applied in multiple ways such as evaluation data sharing, evaluation record authenticity, evaluation result security, etc. This can provide a feasible mechanism for solving the credibility problem of evaluation data in traditional educational evaluation.

2.2. The Frameworks in the Metaverse

Recently, researchers have developed systems in the metaverse, and as Table 1 illustrates, they are primarily centered around VR/AR or blockchain. For VR/AR-based frameworks, the commonly used evaluation items include user experience, interactivity utility, immersion utility, etc., and for blockchain-based frameworks, evaluation items include consensus overhead, computation overhead, throughput, etc. Given the important role of VR/AR and blockchain, it is important to investigate combining these technologies to explore the metaverse in educational evaluation.

Table 1. The frameworks in the metaverse.

Ref.	Year	Framework	Utilized Technology	Evaluation Items
[29]	2021	Edu-Metaverse	VR	△Interactivity utility △Immersion utility △Cognitive utility
[30]	2021	A university campus	VR	△UI display
[31]	2022	VoRtex metaverse platform	VR	△User experience △Virtual world design △Avatar control △Scalability △Security
[32]	2022	RARC	AR	△Utility comparison △Power allocation △Service selection △Convergence
[33]	2022	Technology-enhanced education	VR	△Technological competence △Perceived pedagogical benefits △Necessity
[20]	2023	MetaShard	Blockchain	△Throughput △Running time △Attack probability △Pr51%
[19]	2023	K-Cube VR	VR	△Knowledge gain △Competitive task workload △Spatial UI for content viewing △VR Fatigue
[34]	2023	Blockchain-aided secure semantic communication framework	Blockchain	△Consensus overhead △Computation overhead △Semantic similarity performance

2.3. The Supporting Role of Metaverse

The emerging metaverse is a new type of social ecological civilization that transcends the actual world, and its social ecological civilization is established under the protection of a trusted system. This provides support for the construction of modern educational evaluation, which will be discussed from the following three perspectives.

- Evaluation scenarios. The metaverse realizes the creation of virtual-real integration scenarios, including actual scenarios, virtual scenarios, and custom scenarios that meet

the evaluation requirements. The creation of the above scenarios breaks the space-time boundaries of the real evaluation environment. In terms of spatial expansion, VR and AR technologies have improved the quality of learning [14], such as English learning [35], VR anatomy resources [36], and mobile AR systems [37]. On this basis, they can be used to build realistic evaluation scenarios, so that learners can be immersed in different evaluation scenarios. For example, a communicative scenario can be set up for a language test to evaluate a learner's proficiency with language application. In terms of time extension, evaluation scenarios can be seamlessly switched to change the mode of a single scenario. It also helps learners to naturally integrate into the scenario by activating their integrated senses of vision, hearing, touch, smell, taste, and other senses. To a certain extent, the evaluation accuracy can be improved. Meanwhile, the construction of the evaluation scenarios needs to comply with certain rules and conditions under the blockchain framework, which ensures the security and authenticity of evaluation data.

- Evaluation relationship. The metaverse reshapes the relationship between learners and evaluators, emphasizing multi-dimensional interactions that allow them to interact and communicate in an authentic and natural way, resulting in more accurate assessments. On the one hand, it provides multi-sensory interaction interfaces: speech synthesis, brain-computer interface, somatosensory interaction, and other technologies are used to enable learners to have visual, auditory, tactile, and other experiences [38]. On the other hand, it facilitates multi-identity interaction in evaluation activities. Such evaluation activities can attract more space-time peers to participate in evaluation, such as students, teachers, virtual characters, etc. At the same time, the Non-Fungible Token (NFT) mechanism provided by the blockchain can stimulate the enthusiasm of evaluators.
- Evaluation activities. Diverse evaluation activities are technically supported by the metaverse's characteristics, such as deep immersion experience, community attributes, and group free creation. First of all, the evaluation activities are not limited by time and space, and at the same time, the learners' behaviors can be comprehensively recorded to ensure the acquisition of real and complete process data, which can be used to analyze the learners' comprehensive abilities. Second, the resources used to create evaluation activities can be shared. The resources in the metaverse are distributed on the blockchain, and all nodes can share these resources. This technical characteristic helps to build a fair sharing platform, thus breaking down regional differences and promoting the efficient sharing of evaluation resources.

3. The Metaverse Exploration Framework

Based on the characteristics and supporting roles of the metaverse, we summarize its exploration framework for educational evaluation, as shown in Figure 1. In order to solve the problems of reliability, accuracy, and credibility, we discuss three aspects: acquisition of evaluation data, analysis and processing of evaluation data, and display and storage of evaluation data. With an emphasis on the support of VR, AR, and blockchain for the metaverse, we present the current related work and potential applications from a technological standpoint for each aspect.

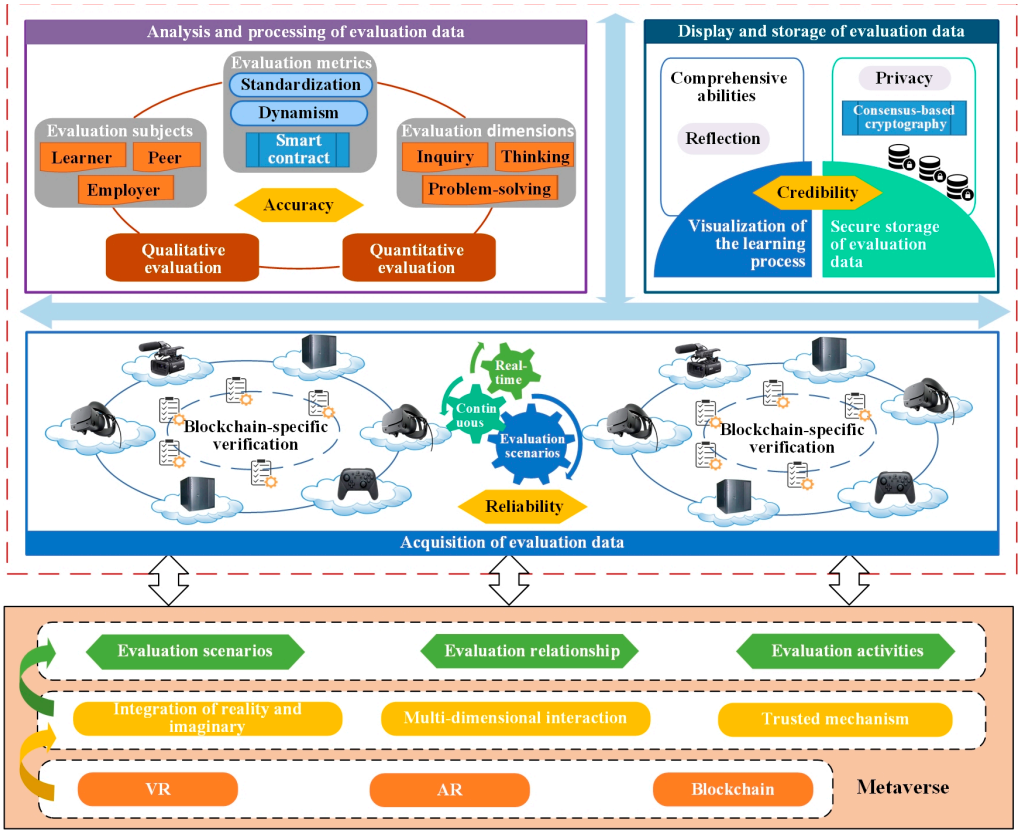

Figure 1. Metaverse exploration framework for educational evaluation.

3.1. Acquisition of Evaluation Data

Evaluation data, which can be acquired by devices in evaluation scenarios created by the metaverse, are the foundation of educational evaluation [39–41]. This way of acquiring evaluation data compensates for the shortcomings of traditional data acquisition by enabling continuous, real-time process data collection and broadening the source of evaluation data, as reflected in the following two aspects. On the one hand, the virtual-real fusion of evaluation scenarios is conducive to capturing the real learning state of the learners. Evaluation data related to learners are collected through the use of AR and VR devices, which can be applied to explain and discover intrinsic learning processes, characteristics, and changes, while facilitating the complementarity of multiple sources of assessment information and the intelligent perception of evaluation scenarios (for example, online learning environments [42], libraries [29], and campuses). On the other hand, blockchain guarantees that the collected data are real and reliable. When data are transmitted through VR or AR devices, they need to go through a blockchain-specific verification process, supported by a consensus mechanism. In particular, blockchain's privacy-preserving technology becomes an available way to address data privacy issues, including security of learners' physiological, physical, and cognitive data. Moreover, evaluation activities take place in open environments (e.g., the Mooc platform), and blockchain technology's transparency and anonymity offer a feasible technical solution to ensure the reliability of data in open environments. To sum up, the evaluation scenarios created by the metaverse eliminate the disconnection between traditional evaluation environments and actual environments, and provide an effective way to acquire evaluation data. However, how to combine VR, AR and blockchain to construct the evaluation scenario is a key issue.

3.2. Analysis and Processing of Evaluation Data

To obtain evaluation results, educational evaluation must analyze and process the evaluation data. There are two categories of primary methods: qualitative and quantitative

evaluation. The former is an objective evaluation that is based on pre-established evaluation indicators; however, because the evaluation criteria are subject to change over time, these metrics are not flexible in evaluation implementation. The latter involves some subjectivity and uncertainty as evaluators evaluate learners. So, one of the major challenges facing educational evaluation is how to improve the accuracy of evaluation data [43,44]. The metaverse provides the technological possibility, primarily in the following three ways.

First, it enables more evaluators to participate in qualitative evaluation. The cross-domain socialization of virtual and real integration based on VR and AR provides learners with a surreal social experience. The expansion of each learner's socialization correspondingly expands the evaluation subjects as follows. (1) Self-evaluation by learners. The learner's unique identifier in the metaverse will accompany him/her throughout the learning process, facilitating ongoing evaluation. (2) Peer evaluation. Learners use their avatars for social interaction and collaborative practical exploration that extends socialization. (3) Employer evaluation. By constructing real work scenarios in enterprises, the evaluation related to learners' problem-solving ability and professional competence is examined from the perspective of employers. The diversification of evaluation subjects is an important guarantee of scientific evaluation. The metaverse has created a new model of multivariate evaluation with the collaborative participation of schools, families, and society, changing the traditional model of relying solely on the school system for evaluation.

Second, it encourages the standardization and dynamism of quantitative evaluation. Using the blockchain, evaluators can modify the rules and guidelines for quantitative evaluation, offering evaluation metrics that are transparent, free, and flexible [45]. Additionally, smart contracts provide a trusted evaluation environment for all participating evaluators, ensuring the transparent execution of the evaluation criteria described in the evaluation scenarios. Examples include the development of a university English evaluation system [46], the integration of on-chain and off-chain data for the students' comprehensive quality assessment system [47], a learning output blockchain [48], a learning process blockchain [49], a digital operating skill evaluation system [50], and a platform for evaluating student competencies [51].

Finally, it has the potential to expand the educational dimensions for the comprehensive ability of learners. The metaverse can assist with activities that evaluate learners in multiple dimensions, including inquiry-based, experiential, thinking capacity training, and complex problem solving. Furthermore, the utilization of multimodal evaluation data facilitates the application of artificial intelligence (AI), leading to a more accurate evaluation of the learner's abilities.

Currently, the application of the metaverse in education is more in the stage of theoretical exploration, such as the concept of education metaverse [52–54]. Despite the existence of some prototype systems [30,55], they are not yet widely used. Therefore, it is imperative to fully leverage the metaverse's advantages and propose novel processing approaches.

3.3. Display and Storage of Evaluation Data

Better learning is evaluation's ultimate goal, and timely, iterative reflection based on evaluation data can be a key component of this. The reflection phase is rarely included in current evaluation research, therefore, one key strategy for encouraging reflection is the logical display of evaluation data. Meanwhile, the credibility of evaluation data is the basis of data display. Metaverse improves storage security while presenting evaluation data in a more comprehensive way.

First, multimodal evaluation data provide the necessary material for visualizing the learning process. For example, videos can reproduce the learning process and be analyzed to uncover underlying factors, thus facilitating learners' reflection and improvement. Traditional tools are learning dashboards [56], e.g., learner-oriented dashboards represented by NoteMyProgress [57] and StepUp [58], which focus on presenting and optimizing the learner's academic performance, and lack the presentation of the learner's comprehensive

ability. The increasing size and variety of evaluation data provided by the metaverse makes it possible to effectively characterize and present learners' comprehensive abilities.

Second, considering the technical characteristics of blockchain, such as traceability, scalability, non-tamperability, decentralization, etc., it provides new ideas for the secure storage of evaluation data [59,60]. Examples include the Educhain blockchain platform for lifelong education records [61], a learning outcome record model for innovative entrepreneurship courses [62], and a tamper-resistant learning tracking repository [63].

Finally, the metaverse protects the privacy of evaluation data. Since evaluation data is shared and publicly available, making them publicly available in a way that protects individual privacy is a challenge. Blockchain uses consensus-based cryptography to protect the anonymity of data, and data can only be accessed by an individual user's private key, maximizing the security and privacy of evaluation data. Although various prototype systems for grade authentication and credit confirmation have been developed to date [64,65], they have not been widely implemented.

In summary, the metaverse provides a possible way for visualizing and securely storing evaluation data to improve the credibility of evaluation. However, how to store large amounts of multimodal data and how to construct mechanisms that encourage learner reflection are urgent issues to be solved.

4. Metaverse-Based Implementation Scheme

Based on the exploration framework described in this paper, this section proposes an implementation scheme and illustrates the application of the metaverse in educational evaluation. The proposed scheme is divided into three main modules: data acquisition, data analysis and processing, and data display and storage.

4.1. Data Acquisition Module

Evaluation scenarios facilitate access to evaluation data. As seen in Figure 2, data acquisition can be divided into three parts: building evaluation scenarios, creating evaluation blocks, and organizing and sharing scenario resources.

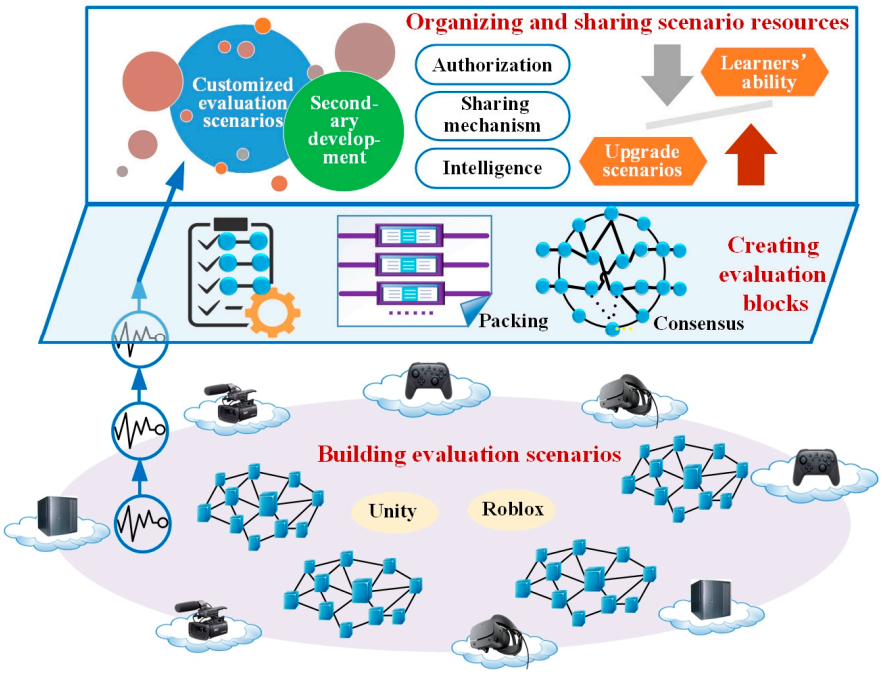

Figure 2. Data acquisition module.

Building evaluation scenarios requires hardware facilities and software. Hardware facilities mainly include the 5G network, immersive devices, and other auxiliary devices.

The immersive devices are mainly high-performance computers that support VR and AR, as well as other auxiliary devices such as handles and projections. Software includes virtual reality software and metaverse platforms, such as Unity, Roblox, etc. In the evaluation scenario, the learner's process data, such as behavioral, physiological, psychological, and virtual identity data, are captured. Note that the acquired data is multimodal, real-time, and continuous.

A blockchain network based on P2P is constructed and an evaluation block generation method centered on the node trustworthiness algorithm is designed, as well as a series of block operations, including the computation function for timestamp verification, the selection algorithm for packing blocks, and the consensus strategy for determining whether a block is accepted or not. The initial block is established using PoS to record basic information of the evaluation scenario. At the same time, different permissions are set for evaluation subjects.

Evaluation scenarios can be dynamically organized in the metaverse by evaluators based on learning objectives. For example, they can customize scenarios for different types of evaluation activities, such as validation and collaborative evaluation. Additionally, the evaluation scenarios are intelligent and adaptable based on the abilities of the learners. Furthermore, the implementation of a smart contract-based sharing mechanism facilitates easy access to the constructed scenario resources for evaluation subjects who possess the requisite authorization, hence aiding in the secondary development of those resources.

In terms of data acquisition, VR and AR technologies are utilized to construct evaluation scenarios and collect multimodal process data, which promotes the complementarity and integrity of evaluation data from multiple sources. At the same time, blockchain technology provides effective technical means to improve the security of the acquisition process, such as consensus verification for data transmitted by VR or AR devices, thus improving the reliability of evaluation data. However, some key issues need to be addressed, such as how to label multimodal data to achieve cross-modal semantic representation and improve scene intelligence, and how to reasonably map the relationship between process data and learning states to facilitate comprehensive analysis of learning states. In conclusion, the acquisition module developed using VR, AR, and blockchain technologies builds metaverse-based evaluation scenarios, providing an effective technical way to obtain comprehensive, valid and reliable evaluation data and laying the foundation for improving the accuracy of educational evaluation.

4.2. Data Analysis and Processing Module

The data analysis and processing module makes full use of the acquired evaluation data to perform evaluation, as illustrated in Figure 3. Evaluation data analysis is the foundation, and data processing includes quantitative evaluation and qualitative evaluation. Quantitative evaluation uses the smart contract mechanism of the blockchain, by triggering the core code of the contract to automatically calculate the values of the perceived evaluation metrics in the scenarios; qualitative evaluation adopts an incentive mechanism to attract more people into the scenarios to participate in the evaluation, and encourages self-evaluation and peer evaluation.

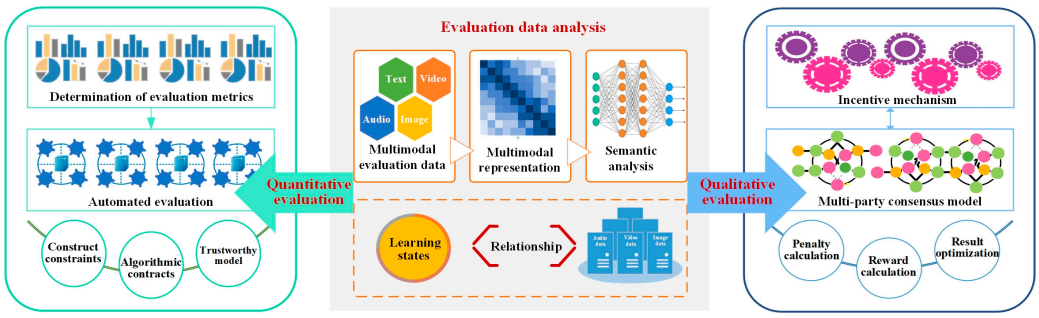

Figure 3. Data analysis and processing module.

For the acquired multimodal data, cross-modal semantic analysis is required to assess the state of the learners in the evaluation scenarios. Semantic analysis focuses on scenario representations of the metaverse and physiological representations of the learner's avatar to explore the relationship between evaluation data and learning states, facilitating the labelling of multimodal data. Also, in order to enhance the complementary information between different modal data, deep learning techniques (e.g., transformer) can be used to construct multimodal representation models through its powerful feature learning capability, multilevel pre-training architecture, and automated coding mechanism.

Quantitative evaluation realizes the standardization and automation of evaluation, including the determination of evaluation metrics and automated evaluation, by analyzing learners' behavioral data in evaluation scenarios, such as searching and browsing behaviors, so as to adaptively determine evaluation metrics based on the unique characteristics of each learner. Based on this, a three-part smart contract design, execution, and credible guarantee-quantitative evaluation method, is constructed. Initially, evaluation metrics are used to construct constraints [66], which are then translated into contract code and stored on the blockchain until the evaluation is complete. Second, algorithmic contracts are generated utilizing evaluation data to guarantee the contract's obligatory, dependent, and observable nature. Lastly, it provides a trustworthy model and offers association design guidelines to improve the credibility of smart contracts.

Qualitative evaluation is a subjective appraisal of a learner's performance by the evaluators, and the more evaluators that are engaged, the more accurate the subjective evaluation will be in some cases [43]. Therefore, an incentive mechanism is designed to encourage self-evaluation by learners and peer evaluation among "space-time peers" in the metaverse, as well as professional evaluation by employers and other similar roles. On this premise, a multi-party consensus model is created to ensure the fairness of the subjective evaluation. This model includes consensus algorithms for penalty calculation, reward calculation, and result optimization. It is worth mentioning that the consensus technique should take into account the dynamics of evaluation due to time.

Traditional evaluation methods are classified as qualitative and quantitative in terms of the processing of evaluation data, but the scientific and non-objectivity of these methods has made educational evaluation difficult [67]. The evaluation scenarios built by the metaverse provide a new starting point to face the above challenge, which are reflected in the following three main points. First, smart contract technology can automatically perform quantitative evaluations to process data with dynamic changes in real time. Second, the interaction technology supported by VR and AR provides a convenient interface for evaluators with different roles to participate in the evaluation. Third, consensus mechanisms provide evaluators with credible guarantees that can evolve with the dynamics of evaluation. In conclusion, the data processing approach increases evaluation accuracy while ensuring the fairness of evaluation results to a certain level. There are still certain particular concerns that need to be resolved, such as creating the multi-party consensus mechanism's constraints and building the smart contract's fundamental logic.

4.3. Data Display and Storage Module

Based on the results of quantitative and qualitative evaluations, the visualization technique is used to display the learner's ability. This allows for real-time feedback to be given to both evaluators and learners. Additionally, as Figure 4 illustrates, mechanisms and strategies for storing evaluation data are designed, including visualization of evaluation data, establishment of the data storage mechanism, and design of data storage strategies.

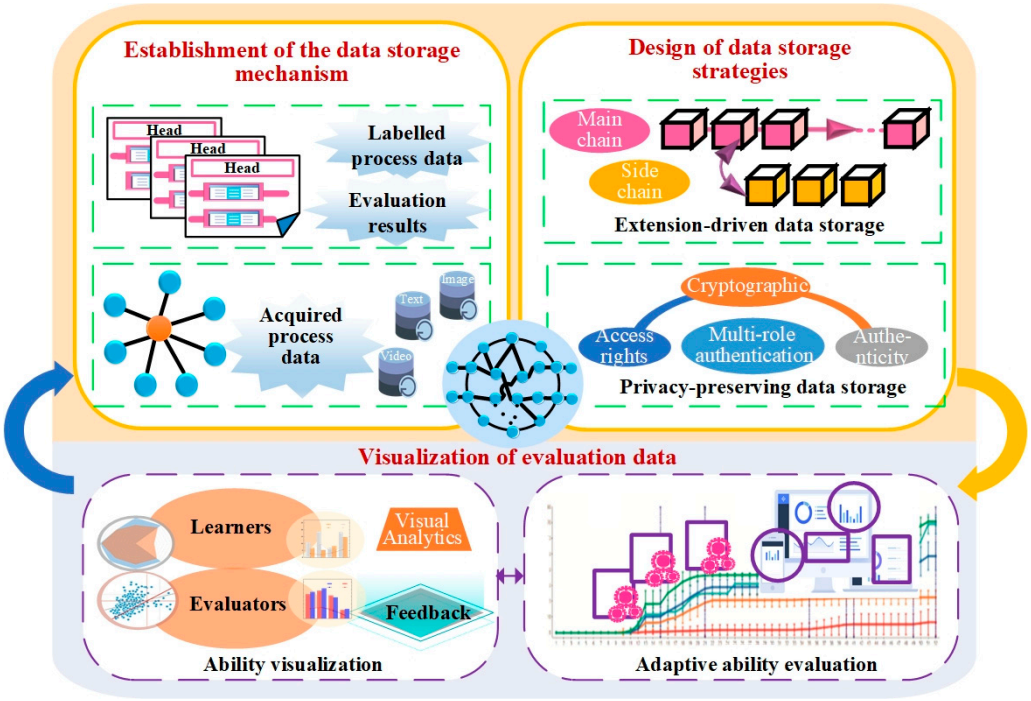

Figure 4. Data display and storage module.

Visualization of evaluation data facilitates adaptive display of evaluation data. Evaluation data is first exhibited through visualization techniques (such as visual analytics) [68,69], and real-time feedback is offered to learners or evaluators. For learners, self-reflection can be done to promote better learning. Meanwhile, evaluators can reasonably interpret and predict learning performance through predictive algorithms such as concept drift [70,71], and improve teaching methods based on demonstrated stage-specific learning evaluations of learners. Based on this, learners' abilities are evaluated in a flexible way. It should be noted that the idea of integrated competency calculation refers to the display of related evaluation metrics based on the requirements of evaluation subjects (e.g., employers, teachers, parents, etc.), rather than the direct calculation of such metrics using mathematical formulas. Furthermore, an evolutionary model-based visualization approach is employed to provide evaluation results from a developmental standpoint. In the meantime, a context-aware access control approach for evaluation findings is designed using blockchain technology, limiting the rights of evaluation data and preventing the disclosure of private information.

Evaluation data can be divided into two categories: process data and evaluation results. Because of the huge volume of these data, it is essential to build efficient storage mechanisms. Blockchain technology uses a decentralized structure, which is obviously not feasible if used to store large-scale process data. Traditional storage methods use a centralized structure to store process data with various modalities. Thus, a data storage mechanism can be constructed using a combination of centralized and decentralized approaches. Specifically, acquired process data, such as images and videos describing learners' behavior, are stored directly in a central database. The labelled process data and evaluation results are recorded in a decentralized manner, i.e., stored in the evaluation blockchain. At the same time, the evaluation blockchain also stores fundamental data in the evaluation scenarios, such as learners, courses, teachers, and other data. For evaluation subjects, different permissions must also be set in the blockchain. Note that data collaboration protocols and data validation protocols need to be designed to ensure the integrity and consistency of the data off and on the chain.

Two storage strategies are designed based on the type of evaluation data: extension-driven data storage for process data, and privacy-preserving data storage for evaluation results. For the former, smart contracts are used to automatically execute the logic of record-

ing process data. Considering the limited storage capacity of the evaluation blockchain, an extension model based on the main chain and side chain can be built, in which the labeled data is stored in the side chain and the basic data is stored in the main chain. In the implementation, the sidechain structure can be designed by adding extra bits to the blocks [72], and a strategy for attaching sidechain data must also be proposed. Further, security permission verification needs to be set up to determine which evaluation subjects have permission to communicate with the main chain.

Evaluation results are stored using a privacy-preserving data strategy, and they are categorized into formal outcome evaluations and informal outcome evaluations. The former, such as degree certificates, requires official certification, while the latter does not. Therefore, a multi-role authentication platform can be built, in which evaluation subjects such as learners, schools, and employers are added, and digital certificates are automatically issued based on learning outcomes. Digital certificates are attached to the evaluation blockchain in the form of blocks using cryptographic algorithms and therefore cannot be modified or deleted, which allows employers or other organizations to verify data and trace the authenticity of the source of the certificate. In addition, the platform grants appropriate access rights to different evaluation subjects, thus better protecting the privacy of stored data.

The metaverse makes it easier to assess learners' abilities by providing personalized visual displays and automatic perception of the evaluation metrics needed for evaluation subjects. Credibility of the data serves as the foundation for storage and display and is a crucial assurance for data evaluation. Blockchain technology proposes and applies many innovative techniques for building credible mechanisms in an open environment, such as public ledger, asymmetric encryption, and consensus. These technologies make the blockchain decentralized, persistent, anonymous, and traceable on the one hand, and tamper-evident and distributed on the other. However, establishing credible mechanisms in a metaverse-based evaluation scenario is extremely difficult due to the intricacy of the components involved in educational evaluation. Challenges include how to develop an extended blockchain structure to meet the demands of storing data in real-time, and how to create smart contracts that allow for the certification of various evaluation subjects. Further research is necessary on the aforementioned difficulties.

5. Implementation Difficulties and Performance Evaluation

In this section, we first present practical guides to the implementation of the proposed scheme, followed by the implementation difficulties and performance evaluation.

5.1. Practical Guides

A metaverse-based evaluation scheme serves as a generalized evaluation application framework that can meet the evaluation requirements of both theoretical and practical courses. It needs more testing and fine-tuning to align it with real-world practices in the process of implementation. Evaluation scenarios are built using course resources, learner abilities are evaluated using both qualitative and quantitative processing methods, and evaluation results are recorded in a blockchain. The following practical guides can be used for scheme implementation.

(1) From the technicians' perspective, they need to develop the evaluation platform and design an easy-to-use human-computer interface for educators and learners. Technicians are required to maintain the metaverse platform's hardware and software concurrently. With the teacher's help, technicians integrate course resources in a targeted manner and choose the appropriate evaluation mode.

(2) From the teachers' perspective, they should work on strengthening their information literacy and mastering the use of interactive technologies in the metaverse. In order to find the best evaluation methods, they should also carefully integrate the course material with the evaluation scenarios. Teachers must adapt to their avatars and interact naturally with learners in the evaluation scenarios.

(3) From the learner's perspective, it is important to become proficient in the various interactions in the evaluation scenarios and to complete the operations required by the evaluation tasks. These tasks include collaborative interactions between multiple learners, as well as interactions between learners and their avatars. To really display their competency, learners have the ability to quickly adapt to new evaluation scenarios.

5.2. Difficulties and Evaluation

Given that the proposed scheme consists of three modules (data acquisition, data analysis and processing, and data display and storage), we summarize the difficulties for scheme implementation and the evaluation items based on the modules, as shown in Table 2.

Table 2. Implementation difficulties and performance evaluation.

Module	Implementation Difficulties	Evaluation Items
Data acquisition	• Labeling multimodal data • Designing the structure of the evaluation data • Designing scenario transitions	◇ Learners' experience ◇ Avatar control utility ◇ Computation overhead ◇ Throughput
Data analysis and processing	• Analyzing learners' behavioral data • Constructing a trustworthy model for quantitative evaluation • Removing malicious evaluations	◇ Match degree between learners' learning status and performance ◇ Accuracy for learners' multimodal data ◇ Macro-F1 for learners' multimodal data ◇ Acceptability of evaluation results
Data display and storage	• Obtaining requirements of evaluation subjects • Designing strategies for data consistency • Designing the extended block-chain structure	◇ Satisfaction ◇ Recognition of learners ◇ Rights management security utility ◇ Authentication security utility ◇ Privacy utility

6. Discussion and Future Work

With its technological benefits, the metaverse can be used to reform educational evaluation. Nevertheless, there are still some issues that need further research.

Concerns about data acquisition and privacy protection. While data collecting from intelligent sensing devices is highly convenient, the data are obtained in a laboratory setting with specific research limitations for their unnatural, experimental, and independent individual research and analysis. Simultaneously, privacy protection challenges are especially salient since the obtained data pertaining to learners encompasses physiological, physical, and cognitive information, all of which require safeguarding.

Blockchain, VR, and AR working together in the metaverse. Certain applications, such as virtual campuses, are made possible by VR or AR. Blockchain technology is being used to create evaluation systems. All of the previously listed options have certain advantages in terms of technology, but they also have certain disadvantages. By combining these technologies, the metaverse encourages the complementary benefits of each one. It fully utilizes VR and AR to enable human-computer interaction and employs blockchain technology to guarantee the reliability of interaction data. Simultaneously, this will address the enormous difficulty of integrating technology, namely how to integrate VR, AR, and blockchain into the metaverse, and how to make them collaborate in the metaverse. These are all issues that require further research.

Proposal of theoretical methods of the metaverse empowering evaluation. The metaverse empowers educational evaluation scenarios to reconfigure novel human-computer interactions and help educators propose more effective evaluation methods than traditional education. Thus, it is necessary to study the cognitive mechanisms of evaluation under the new human-computer interaction, and analyze dynamic cognitive processes of learners in

evaluation scenarios. Therefore, researchers need to propose new theoretical methods to improve the reliability, accuracy, and credibility of educational evaluation, which would promote the application and dissemination of relevant outcomes in the field of education. Furthermore, it is challenging to evaluate the proposed methods since educational evaluation is a complicated field involving many factors.

7. Conclusions

In this study, we provide a solution for educational evaluation using the emerging metaverse technology. We first analyze the characteristics of the metaverse and demonstrate the supporting role of VR, AR, and blockchain. Then, we present a metaverse exploration framework and show its feasibility for solving the problems of reliability, accuracy, and credibility in educational evaluation. Based on this, we propose a metaverse-based implementation scheme, which consists of three modules: data acquisition, data analysis and processing, and data display and storage. Also, we show practical guides, difficulties, and evaluation for implementing this scheme. Finally, we discuss the research issues for future work, including privacy protection, the integration between VR/AR and blockchain, and theoretical methods by which the metaverse can empower evaluation. We believe that this paper can help researchers create a reliable, fair, and credible ecosystem for educational evaluation.

Author Contributions: Conceptualization, L.Z. and X.C.; methodology, L.Z. and X.C.; investigation, L.Z. and X.C.; resources, L.Z. and X.C.; writing—original draft preparation, L.Z. and X.C.; writing—review and editing, L.Z. and X.C.; visualization, L.Z. and X.C.; supervision, L.Z. and X.C.; funding acquisition, L.Z. and X.C. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Key Program of Chongqing Education Science Planning Project (No. K22YE205098) and the Doctoral Research Foundation of Chongqing Normal University (No. 21XLB030, No. 21XLB029).

Data Availability Statement: The data supporting this review are from previously reported studies and datasets, which have been cited.

Conflicts of Interest: The authors declare no conflicts of interest.

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