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Education Exchange Storage Protocol: Transformation Into Decentralized Learning Platform

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The current micro-teaching process is readily online, and it is functional anywhere and anytime ubiquitously. All or most teaching and learning activities are accessible in centralized storage. However, centralized storage has inherent problems, such as a single point of failure with many possible data breaches, much duplication of data stored repeatedly in one location, and the lack of trust in third parties for data stored in centralized storage. Further issues include the high cost and low performance of the online systems that hinder the quality of the education process. In this paper, we propose a new framework Education Exchange Storage Protocol (EESP). EESP aims to improve the efficiency of the decentralized storage ecosystem in micro-teaching, coupled with blockchain technology acting as a control layer. Blockchain empowers the decentralized system by bringing together the most incompatible unstructured entities and integrate them. The decentralized storage system is armed with a blockchain smart contract that acts as a control layer, featuring impregnable security, immutability, trace-ability, and transparency. The EESP framework aims to elevate teaching and learning through blockchain decentralized storage systems in a transformational way, including but not limited to things like micro-credential, massive open online courses, and gamification, all in a single immersive learning platform. Finally, we tested and evaluated this framework using the truffle simulator, and the results demonstrate that the EESP model significantly improves performance.

Keywords: blockchain, decentralized storage, education, micro-teaching, EESP

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1 INTRODUCTION

The entire education sector landscape has shifted because of the Covid-19 pandemic outbreak. Schools and colleges remain closed indefinitely; fear of losing hope for the future resonates worldwide (Watermeyer et al., 2021). The children from kindergarten to K12 and colleges stay at home and are constrained to study exclusively online. This negative impact affecting life and lifestyle is preeminent (Wang et al., 2018a), like never before in centuries. Families around the world are especially concerned about the education of their children. There is an urgent and immediate need to save our children's future, and this situation calls for unity and humanity (Palacios et al., 2019).

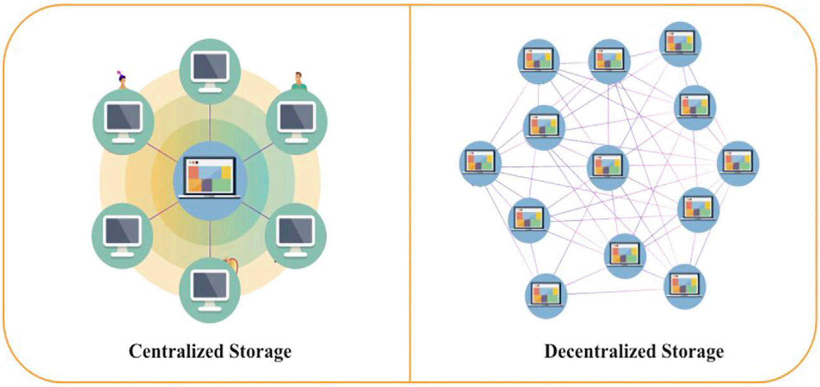

FIGURE 1 | Centralized Storage vs. Decentralized Storage.

As a consequence of the pandemic (McElroy et al., 2020), technology undoubtedly remains the only vital turning point that can usher a fundamental structural shift in education (Vimal and Srivatsa, 2019). The change is paramount; it not only alleviates the impact of the pandemic it also accelerates learning. The digital transformation is unprecedented in improving productivity by increasing student engagement and motivation. Various new models of connections in an integral teaching and learning platform are overwhelmingly introduced by developers (Rich et al., 2021), linking teachers and students to invaluable professional resources and experiences that entirely improve personalized learning like never before. Flexibility in learning, in terms of preferred day and time, or personal favorite places to engage in teaching and learning (Yates et al., 2021), the people in this era of civilization have the incredible opportunity to enjoy the unprecedented ubiquitous learning experience.

Although many attempts to offer the best education platform worldwide, people still demand something unique that fits everybody's education needs. Too many education platforms are readily available to the public (Kwon et al., 2020), and which one will tailor best to our needs remains questionable. Unclustered learners are making trial and error, wasted time and resources spent fruitlessly testing unproductive learning platforms. How wonderful if time and resources could be on productive learning rather than navigating aimlessly on identifying suitable learning platforms.

So many technologies combine and converge to form the learning platform, this research aims to focus on the storage for micro-teaching (Poitras et al., 2021). For micro-teaching to be effective, much data needs to be readily available to teachers and learners. And up to the current technology in time, the most necessity of storage for micro-teaching remains in a centralized database (Chiu, 2021). These configurations are largely prone to a data breach on confidential and sensitive data. As shown in **Figure 1**, another problem in the centralized system is congestion, which has a single natural point of failure. If this point of failure is misused, it can easily lead to data loss or leakage. Consequently, higher education typically implements security policies that restrict access to sharing of records in micro-teaching to protect personal information (Yuan, 2020; Erdemir and Yeşilçınar, 2021). Even if the centralized storage system is reserved for data availability, the centralized storage service provider may still experience Force Majeure factors (such as political censorship) that prevent users from accessing their data (Wang et al., 2018b).

In addition, it is a common practice that users often store the same micro-teaching data repeatedly in one location (Ledger and Fischetti, 2020). The attempt causes inconsistent data redundancy and consumes unnecessarily large data storage space, leading to the increased overhead cost of centralized cloud storage services. At present, decentralized storage already costs a lot cheaper than popular centralized storage (Munson and Hu, 2010). Not only that, the data stored on third parties may be corrupted or altered, thus causing the whole system to be compromised (Xu et al., 2020). Centralized multi-tenant data architectures directly risk that user's proprietary data is vulnerable to unauthorized higher education competitors or malicious attackers. Cloud service providers could sometimes be dishonest, enticed, or swayed by some personal interest (Pu et al., 2020; Lang et al., 2018). Due to efficiency demand, they could discard unused or infrequently accessed data to save storage space while claiming it is still adequately maintained in the cloud. As a result, higher education must ensure that their micro-teaching data is appropriately accessible in the cloud by making multiple timely backups. Moreover, data leak cases like Facebook-Cambridge Analytica have resulted in a substantial shift from centralized to decentralized data storage systems at the time (Fahey and Hino, 2020).

Underpinning this research is from the above point of view; the future of education requires a decentralized storage approach. The challenge remains on the control and accessibility of the asset: to deliver the packages with great security control; to ensure self-sovereignty of the assets; to provide provenance and traceability of the assets; to prevent any tampering of data by making it immutable; to ensure the transaction of data without intermediation (Cai, 2018). For this, we propose a new framework, EESP, to efficiently achieve decentralized storage in micro-teaching by combining with blockchain technologies as a control layer. No more worrying about a single point of failure, data compromised, or data inaccessible issues. There will be no more data in repeated fashion and also eliminating third parties.

The remainder of this paper is organized as follows. Part II includes related work describing micro-teaching, blockchain education, decentralized storage, peer-to-peer, and content-addressable storage. The schematic of the system is described in detail in Part III, starting with an illustration of centralized storage issues, and follows with the EESP proposed framework. The framework is further elaborated into smart contract design and algorithm. Subsequently, Part IV presents a case study to prove the working scheme. Finally, we wrap up the research by summarizing the conclusions and the research implications. Future challenges suggest the direction of future research that will naturally be conducted by the authors of this paper or other authors interested in this research domain.

2 RELATED WORK

To fundamentally understand the flow of the research, this section discusses several knowledge and technologies relevant to our work, such as Micro-teaching, Blockchain Education, Decentralized Storage, Peer, and Content Addressable Storage.

2.1 Micro-Teaching

Micro-teaching is a relatively new invention in teacher education that utilizes a professional development tool in both pre-service and in-service teacher education programs (Orland-Barak and Wang, 2021). Micro-teaching enables teachers to understand teaching and learning processes better and develop teaching abilities, examine their teaching, and examine the teaching of others. From the learners' perspective, micro-teaching provides transparency and flexibility to learners by providing continuous assessment and prediction towards the learning pathway (Binder et al., 2021; Márquez-Ramos and Mourelle, 2018; Bouilheres et al., 2020). Both teachers and learners benefit from advancing technologies such as the internet of things, artificial intelligence, machine learning, deep learning, and blockchain (Xie et al., 2020). Those technologies converge to provide unparalleled vital services such as involuntary recommendations, advice, and predictions towards teachers' and learners' pathways of the education journey. This guidance further ensures collectible assistive information (Spyridonis and Daylamani-Zad, 2021) to uplift education experience and quality to a new level. The underlying foundation is the need for reliable storage, a receptacle where Micro-teaching stores and combines a massive amount of structured and unstructured data (Isaac et al., 2020). Structured data include grades, course material, and assignments. Unstructured data include CCTV captured data, video streaming, and audio files (Subudhi et al., 2019). All reliable data must be readily available for the AI technologies (Coghlan et al., 2021) to learn and adapt to the assigned task (Andriella et al., 2020). The trainee teacher re-teaches the micro-lesson based on the feedback, incorporating the points highlighted by the artificial intelligence dashboard recommendation (Mellit and Kalogirou, 2021).

2.2 Blockchain Education

As a decentralized network, Blockchain does not require a central control point or a single storage poin (Rahardja et al., 2020). Blockchain is a decentralized, immutable, and trusted distributed ledger and provides a secure, stable, transparent, audit-able, and effective way to record transactions and interactions of data information (Farahani et al., 2021; Lu, 2018). A typical example of a blockchain is shown in **Figure 2**.

The process of creating new blocks is known as mining. The first block is called the genesis block (Gramoli, 2020). Since there is no previous block, therefore the previous hash in the genesis block is zero. The new blocks are always appended at the end of the blockchain. Every block consists of at least five main items: timestamp to indicate the exact time when the block was created; nonce to accommodate mining of the block; the previous hash that serves as a connecting chain with the previous block; the hash of the current block; and finally the collection of the transactions in the block (Zhang et al., 2019; Dorri et al., 2019). The main components behind the blockchain architecture include Transactions, Blocks, Cryptography, Smart Contracts, Consensus Algorithms, and P2P network. Storing information on the blockchain ensures the originality of the data and solves the security problem of the central authorization mechanism (Yin et al., 2020). Users cannot change the data stored on the blockchain arbitrarily due to the immutable property of the blockchain. Therefore, it functions as evidence to verify the originality and fluidity of the data. Haiyang Yu et al. proposes an efficient continuous big data integrity checking scheme for blockchain-powered decentralized storage (Yu et al., 2021). Their scheme can check multiple files randomly in each time slot, enabling them to verify the integrity of big data for the entire storage period with a high probability of verification. Sujit et al. are also considering connecting traditional e-health service providers via the BC backbone for seamless patient data exchange with strict access control. This approach allows for off-chain information storage for big data that cannot be part of the main chain.

Blockchain technology is responsible as the engine behind the rise of cryptocurrency. Blockchain is also applied to other financial sectors, the health, IoT, government, and education sectors. Halvdan Haugsbakken et al. discuss the potential value of blockchain technology in higher education and identifies areas where the technology can increase speed, efficiency, and transparency (Haugsbakken and Langseth, 2019). Furthermore, according to (Abbasi et al., 2021), the blockchain concept has demonstrated the potential of current educational opportunities. According to (Alammary et al., 2019), the application of blockchain technology to education is still in its very early stages, and there is plenty of room for discoveries. So, an examination of cutting-edge blockchain research in the field of education should be rigorously carried out. Additionally, according to (Guo et al., 2020), they propose a blockchain-enabled digital rights management system that effectively manages online educational multimedia resources. Their

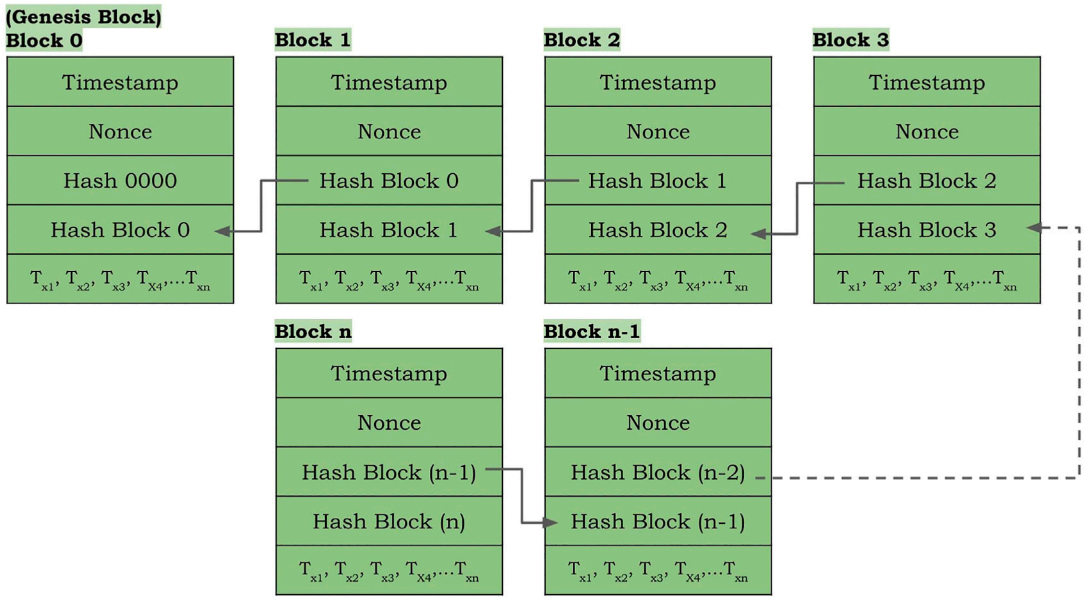

FIGURE 2 | A blockchain scheme.

research uncovered an entirely new network architecture for sharing and managing online educational multimedia resources based on a combination of public and private blockchains, as well as three special smart contract schemes for the realization of multimedia digital rights recording, secure storage, and verification without intermediaries (Vacca et al., 2020).

Uni-Chain was designed by Daraghmi et al. (2019) to be compatible with existing EAR databases and provide inter-operable, secure, and efficient access to EAR by universities, students, and third parties while protecting student privacy. According to their findings, universities are responsible for blockchain maintenance, including creation, verification, and addition of new blocks, while allowing students to control access to their EARs securely. Saleh et al. (2020) proposed a blockchain-based model for verification of graduation certificates to improve the verification mechanism by embedding the SHA-256 hash of any data string in the digital signature embedded in the academic certificate to facilitate verification. Other researchers have tried to increase the digital academic record verification system based on blockchain technology that can be very useful in situations where international companies or educational institutions require verification of one's academic records (Ocheja et al., 2019). Since the digital identifiers given to graduates can be used globally, they can be assigned to anyone anywhere in the world for fast record verification (Lee et al., 2020). With the current general trend in the development and transformation of global education, blockchain technology is expected to emerge as an essential role in developing the "Internet + education" ecology (Qurotul et al., 2020). Research into the educational implications of blockchain is moving rapidly (van Hoek, 2019). Therefore, based on previous studies, there is no existing ideal educational framework design that readily stores and processes all micro-teaching activities quickly and transparently in a decentralized manner.

2.3 Decentralized Storage

Based on the above discussions, decentralized storage is related to blockchain technology in supporting the storage process of micro-teaching activities in education. As shown in **Figure 3**, the peer-to-peer nodes in decentralized storage contain stored data readily obtainable whenever needed by many sectors. Such research (Yazdinejad et al., 2020) aims to use blockchain to authenticate new patients decentralized in a distributed hospital network. It is demonstrated, for example, that the proposed architecture for decentralized authentication among distributed connected hospital networks does not require re-authentication. The researchers in Jiang et al. (2020) introduced Searchain, a blockchain-based keyword search system. It enables an oblivious search over an authorized keyword set in the decentralized storage. This mechanism aims to assure private search over authorized keywords with entire retrieval orders. The research (Liu et al., 2020) explores the architecture for transforming centralized degree internship certification and validation into a decentralized ledger of secure databases. BC technology in the DA validation process further encourages employers to engage with universities systematically from the early stages of developing degree apprenticeship standards. This researcher (Ouyang et al., 2021) proposes a combined learning process managed by a blockchain-based decentralized storage consensus mechanism to prevent bias and privacy leakage from central aggregation unity. IntegrityChain, a decentralized storage outsourcing framework providing the feature of data integrity auditing, has been introduced by the authors of (Li et al., 2020). In another effort (Savazzi et al., 2020), researchers proposed a fully decentralized storage (or server-less) learning approach: the proposed FL algorithms leverage the cooperation of devices that perform data operations inside the network by iterating local

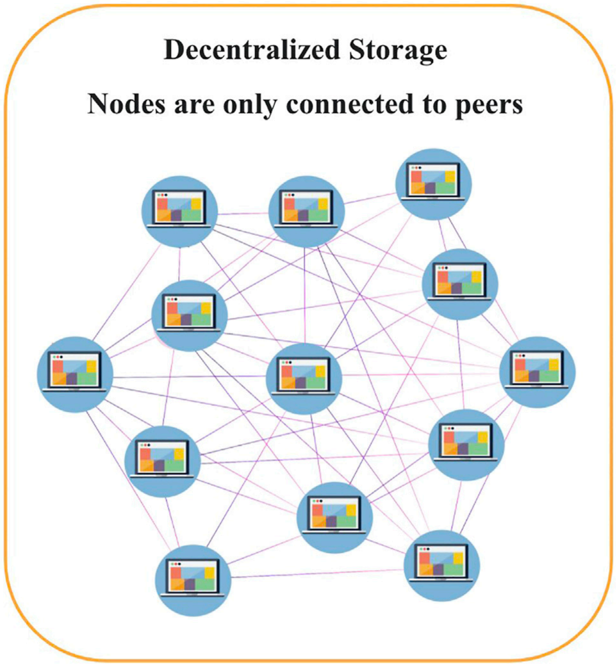

FIGURE 3 | Decentralized storage.

computations and mutual interactions via consensus-based methods. In particular, Lyu et al. (2020) build a fair and differentially private decentralized storage deep learning framework called FDPDDL, enabling parties to derive more accurate local models reasonably and privately by using their developed two-stage scheme.

Because of its benefits in terms of reliability, availability, and scalability, distributed cloud storage has gotten greater attention, and it presents both possibilities and problems for distributed data storage transactions. Traditional storage transaction systems, which are often centralized, result in high costs, vendor lock-in, and the danger of a single point of failure (Gu et al., 2018).

All of the above introduced decentralized storage applications to various business sectors, but few focus on the area of control required for the data in the micro-teaching domains. The question remains on protecting proprietary intellectual rights on the digital assets in the education sector, especially addressing securities issues in terms of the combination of self-sovereignty, immutability, trace-ability, provenance, and disintermediation.

In this research, we present a decentralized transaction technique for cloud storage based on a smart contract that considers the resource cost for distributed cloud storage to alleviate the drawbacks described above.

2.4 Peer to Peer (P2P)

A peer-to-peer (P2P) (Liu et al., 2019) storage system consists of two roles: data owner and data requester. A data owner holds a set of data objects and intends to share them with a certain subset of nodes: its corresponding data requesters. In a P2P storage system, each node can be both a data owner and data requester of other data owners, simultaneously. There have been many peer-to-peer file-sharing applications all over the world (Li et al., 2018). This incentive considers the security and replication of files or resources during the process of transfer, the authors of suggest to take advantage of a hierarchical data structure of a structured P2P and supports proximity-aware and interest clustered file-sharing systems. In another effort (Hassanzadeh-Nazarabadi et al., 2019), they introduce the Pyramid, which is the first fully decentralized utility-aware and locality-aware replication approach for Skip Graph-based P2P cloud storage systems. Pyramid is locality-aware as it minimizes the average latency between nodes and their closest replica. To improve the P2P file system scheme based on IPFS and Blockchain has been studied by the authors of (Naz et al., 2019), the research is to address the high-throughput problem for individual users in IPFS by introducing the role of content service providers. In another effort, the authors argued that violent extremists are experiencing difficulty maintaining viable, persistent presences on social media platforms. With P2P blockchain-based online platforms, an untenable approach to counter-extremism can co-exist. Surveyed the consensus mechanisms and the agreement protocols designed for distributed systems, such as blockchain platforms and P2P-based systems. They identified that the probabilistic consensus mechanisms tend to sacrifice consistency on CAP theorem, and safety on the FLP impossibility, to achieve consensus.

And in education, as shown in **Figure 4** proposed by the authors of (Hashemipour et al., 2021), each peer in the P2P grid represents a participating teacher, and an overlay is formed to represent the neighborhood relationship of participating peers. Also, a peer can join/leave the P2P grid at any time, which characterizes the dynamic nature of P2P grids. To conduct teaching material sharing, a peer installs the tailor-made software, which supports Blog-like operations, such as publication, comment/reply, content organization, etc. In addition, the functions of teaching material search and download are incorporated. In particular, (Ng et al., 2021) proposed a P2P mobile learning model, which shapes the essential interface between the mobile terminals and the web applications. The proposed model is validated via effective trade-off among timely response, individual learning-oriented content management, and multimedia streaming-based peer-to-peer interactivity. They implemented this model using a web-based chat room, achieving a plausible teaching-learning effect. An idea from (Nicholls and Altieri, 2018) is to take advantage of widely-spread and adopted P2P networks for disseminating learning objects, considering them as an ideal means for creating collaborative communities of learners with similar interests. The authors of (Al Ridhawi et al., 2018) introduced a new framework for a more efficient learning environment by using P2P architecture and Semantic Overlay Network. This solution will help inefficient management of LCMS components and improve the performance of LCMS through the RLO. There is even an online reinforcement learning-based approach developed by the authors of (Pouamoun and Kocabaş, 2021) to take advantage of the dynamic run-time characteristics of the P2P IR system represented by information about previous search sessions. Therefore, there is still scarcity in locating in-depth research regarding integration of P2P, blockchain, and decentralized storage to be used in micro-teaching processes.

2.5 Content Addressable Storage

Content addressed storage, also known as CAS, is an object-based system designed for storing and managing fixed content data. It is intended for the safe online storage and retrieval of fixed content, as

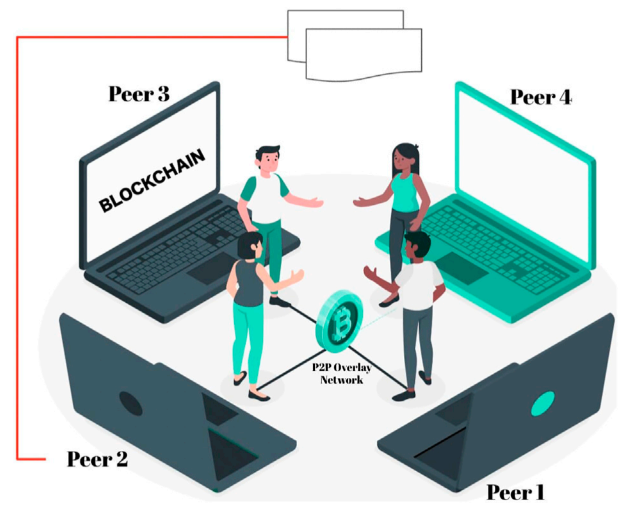

FIGURE 4 | P2P content sharing.

opposed to location addressed storage, also known as LAS. According to (Ullah et al., 2020), databases increasingly use CAS for storing backup information, and snapshots. The process of content-addressable storage is when requesting a particular resource, there is no need to specify a location, it only needs to determine what to look for. In CAS, we request using their cryptographic hash identifier to retrieve the intended item, where the location of the item itself is completely irrelevant. The hash of each file acts as a unique identifier in the form of digital fingerprint. Retrieving the file simply requires the data requester to broadcast the hash key that belongs to the file. Once requested, the network will ping and attempt using the content identifier CID, to locate the nearest decentralized nodes that contain the desired data. PLEDGE is introduced by the authors of (Makhdoom et al., 2020), an efficient and scalable Security Protocol for protecting fixed-content objects in CAS architectures. Moreover, PLEDGE transparently stores sensitive objects encrypted (partially or totally) in the CAS storage nodes without affecting the CAS storage system operation or performance. It also takes into consideration the processing load, computing power, and memory capabilities of the client devices which may be constrained by limited processing power, memory resources, or network connectivity. Since blockchain systems operate on a peer-to-peer network, the main characteristic of blockchain technology is its natural decentralization (Esmat et al., 2021). So, this research underpin the combination of blockchain technology, decentralized storage, P2P, and content-addressable storage need to conduct in order to create a new trend in the education sector to store all micro-teaching assets.

3 PROPOSED SCHEME

This section will present the issues of centralized storage and the need to conduct the protocol framework of educational exchange storage protocol.

3.1 Centralized Storage Issues

The information contained on the Internet is mostly used in centralized storage, most of us are familiar with it. However, from a technical perspective, it has its own issues. Some of the issues are listed below:

1. The threat of a single point of failure in the education sector is that if one server dies or does not function, the entire system will stop too. The user cannot connect to the server, so the system cannot process requests to provide micro-teaching data. Moreover, if there is no backup, users can immediately lose the micro-teaching data. Hence, it can cause very low data availability issues as well.
2. There is a trade-off between cost and performance. Storing the same data and large micro-teaching files repeatedly on centralized storage causes high redundancy. It will overload the system exponentially and makes it a big disadvantage for higher education.
3. There is no micro-teaching data network access control on third-party storage space, so it can be used as a crime such as hacking, spamming, duplication, and even being sold to irresponsible parties.

3.2 Education Exchange Storage Protocol

Inspired by the above literature and as far as we know, we are the first to conduct extensive research on combining blockchain and decentralized storage in a P2P environment. This study proposes the Education Exchange Storage Protocol (EESP) which can support the micro-teaching process in higher education and can gain more benefits than data storage and sharing in traditional centralized storage systems. EESP is in the form of protocol because it consists of rules and sequences to make decentralized storage platform functional. Additionally, we use a framework (**Figures 5–7**) to explain the flow of the protocol in a simple and understandable. EESP is P2P among the academic community in higher education.

As can be seen from **Table 1** and **Figure 5**, there is an EESP flowchart for micro-teaching in the field of education to make it easier to understand the algorithm design. Starting from users, namely students, lecturers, universities or management, alumni, and the general public. Registered users such as students and lecturers have the right to upload micro-teaching assets. The micro-teaching asset upload process occurs at the off-chain layer, when the user uploads the system will make a request to the server to save the user's assets to the off-chain with Rest API, of course, in this process a queue occurs. However, this process happens so fast that users will not feel any delays due to queues. Furthermore, EESP will first check the micro-teaching assets received, to find out in advance that these assets have never been stored on the EESP network. If the same micro-teaching asset already exists on the blockchain network then the request made will be rejected. When the micro-teaching asset has been confirmed not to be stored in the EESP, the process will continue. EESP will automatically convert assets to Chunk, Digest, and Content Identification (CID). After the CID is successfully created the asset will be distributed on the EESP P2P network to generate a

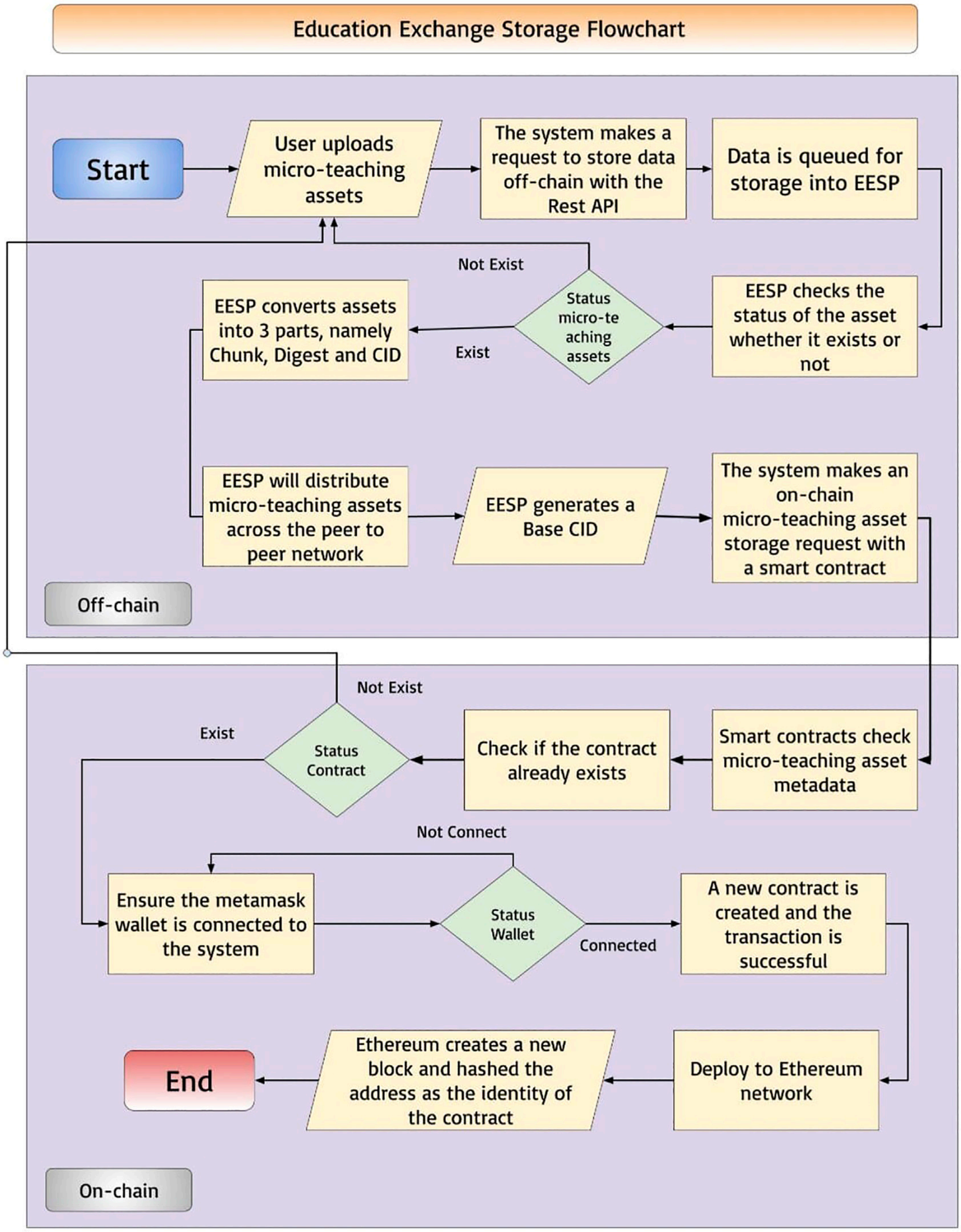

FIGURE 5 | EESP framework part 1.

Base CID as the identity of the asset. The process is continued by the server that makes a request to store data at the on-chain layer. Before the micro-teaching asset is received, the smart contract will check the micro-teaching asset through its metadata. Then, it performs checks to ensure that a contract with the micro-teaching asset has never been created on a public blockchain network. If the contract already exists, then the request will be rejected and the process cannot continue with the same micro-teaching asset due to the nature of the blockchain which rejects duplication. After the inspection is complete and declared accepted, the system will ensure that the user's wallet is connected to the system. After all the requirements have been met, a new contract will be created and stored in the blockchain network. A new block will be created that stores

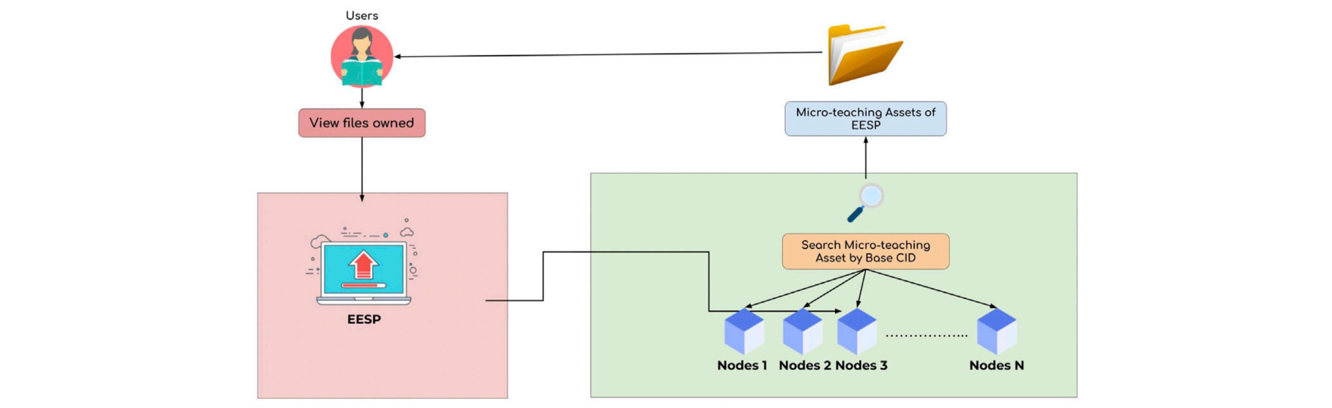

FIGURE 6 | EESP framework part 2.

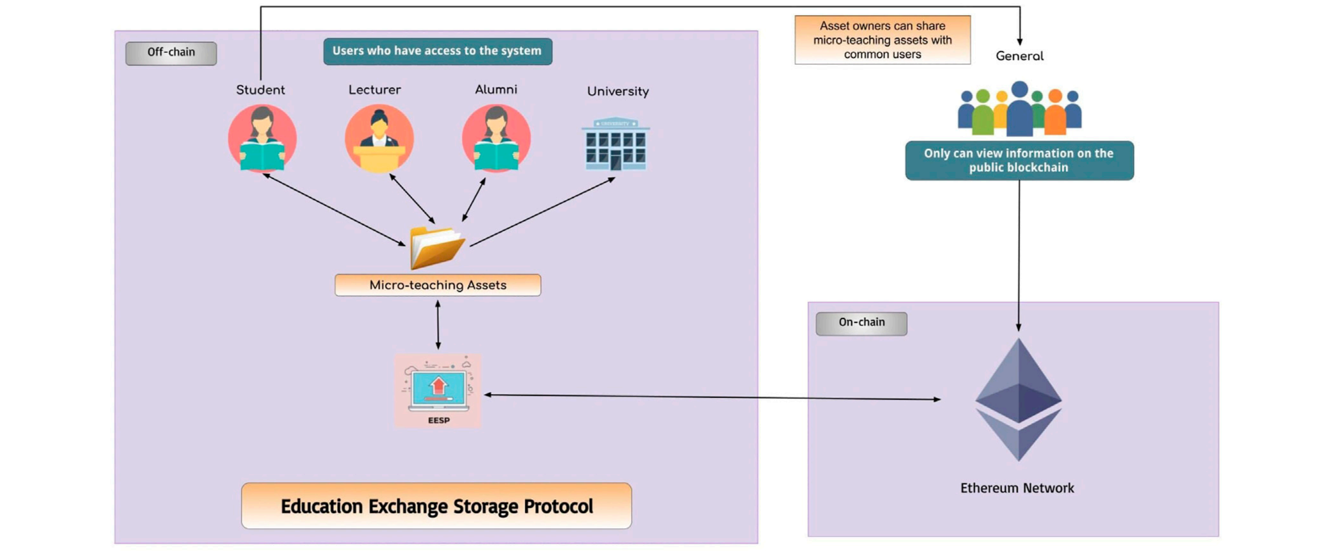

FIGURE 7 | EESP framework part 3.

TABLE 1 | Civitas scheme.

Users
Student
Lecturer
Management
Alumni
General

information about the contract made, the hash of the block will become the identity of the micro-teaching asset in the blockchain public network.

As can be seen from **Figure 6** when the user wants to view the assets from the micro-teaching that have been stored in EESP, the user needs the CID generated by EESP, this CID is stored on the Blockchain Data Storage platform on each asset owner account. EESP will leverage when there is a request to view assets. Verify using the Base CID, and this search will be performed on all connected nodes on the EESP network. when the asset, then the user can see it as a complete undivided asset found.

User access control within the blockchain public network is so limited that general users can only view the information of the contracts made, but general users cannot view the assets of the EESP users as can be seen in **Figure 7**. General users need permission from the owner of the asset and are required to have access to the EESP system in order to view the asset.

3.2.1 Smart Contract Design

Smart contracts have three distinguishing characteristics: autonomy, decentralization, and self-sufficiency. According to autonomy, smart contract creators are no longer needed once the contracts are deployed on the blockchain.

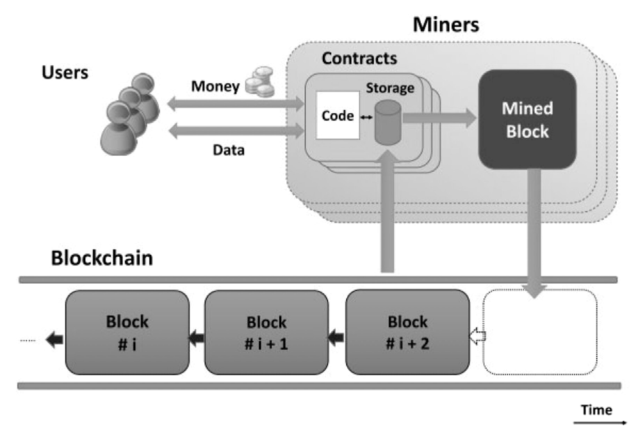

FIGURE 8 | Smart contract system? (Delmolino et al., 2016).

The schematic of the smart contract is depicted in **Figure 8**. Each contract will be allocated a unique 20-byte address. The contract code cannot be changed once it is applied to the blockchain. Users can only submit transactions to the contract address to execute them. Each consensus node (also known as a miner) on the network will then perform these transactions to reach a consensus on its performance. The contribution of this research is to automate the issuance of degree certificates on the blockchain upon completion of the degree using smart contracts. Results are to address unmanaged risk, bureaucracy, human intervention, and fraud. In this study.

From present **Figure 9**, user assets that are ready to be stored on the blockchain will get the help of smart contracts to eliminate third parties from contracting asset storage transactions so that asset security is guaranteed. There is the structure of the smart contract used, written using the solidity language that was specifically created to create smart contracts on various blockchain platforms. After the user's asset is received, the smart contract will check the metadata of the asset, the smart contract will create a new contract that contains five main elements, namely EESP Hash, File Hash, Date Added, Owner and Exist.

3.2.2 Algorithm Design

In this section the logic and algorithms of EESP are explained in detail. This research focuses on using the Solidity programming language to create Smart Contract designs. There are special variables and functions for processing assets integrated on a decentralized network. We mainly use the following special variables:eespHash: the hash generated after the asset is successfully stored into the EESP distributed network, the hash is used as the identity of an asset that stores information about the stored asset or is known as CID (Content Identifier) and can be used to access the stored data.fileHash: this hash is generated automatically after the eespHash CID is stored in the Blockchain network, the benefit of this fileHash can provide a guarantee of the validity of the content stored in the EESP network.dateAdded: is information about the time when the asset storage process was carried out by the user. Owner: Is the owner of the data that carries out the process of storing assets into the EESP and Blockchain, and has full control over the data stored. Exist: Used to ensure that there is no duplicate content either on the EESP or on the Blockchain network.

Algorithm 1. Store File to Blockchain

```
Input: aset_parameter(eespHash, dateAdded,
owner, exist)
Output: string

get DocInfo ()
        string eesp_hash;
        uint date_added;
        bool exist;
end

 HashAdded(string eesp_hash,
 uint date_added);

if (collection[eesp_hash].exist == true)
    then
        docInfo = DocInfo(_eespHash,
        _dateAdded, true);
        collection[_filehash] = docInfo;
        store HashAdded(_eespHash,
        _dateAdded);

        return "File uploaded successfully"
    end
else
    then return "This file already exists
    in contract";
end
```

Get DocInfo() is a function to get the data that the asset owner wants to store, in this case the smart contract will check some metadata, namely eespHash, dateAdded and exist.HashAdded function is used to store multiple asset parameters derived from user assets as an array.

Collection [***eesp$_h$ash***] function is useful to ensure that the asset to be stored is not duplicated, if it is found that the asset already exists then the storage fails.

store HashAdded after going through the inspection process and it is stated that the assets are not duplicated, the smart contract will be executed and a new transaction will be created on the Blockchain, in which it stores the information obtained from HashAdded.

Algorithm 2. View from Blockchain

```
Input: aset_parameter(eespHash, fileHash,
dateAdded, owner, exist)
Output: String

get (string _fileHash) public view returns
(string, string, uint, bool)
    then
        return (
                _filehash,
                collection[_fileHash]
                .eespHash,
                collection[_fileHash]
                .dateAdded,
                collection[_fileHash].exist
            );
    end
End
```

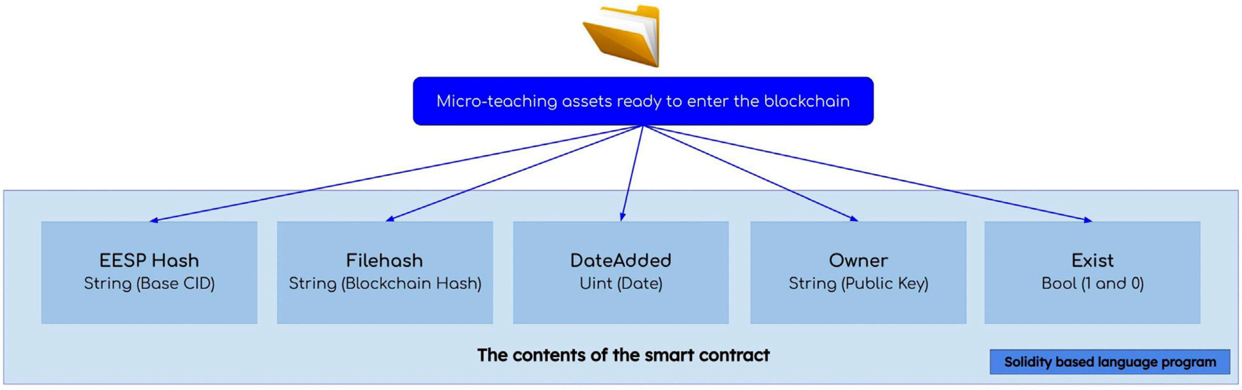

FIGURE 9 | Structure of smart contract EESP.

get(string_hash) This function is used to access assets stored in Blockchain decentralized networks. In order to obtain access rights to the targeted asset, a hash generated after the data storage process into the Blockchain is required. The result of this function will display a string of data that comes from the asset metadata, namely fileHash, eespHash, dateAdded and availability status.

Algorithm 3. EESP Store File

```
    response = fetch('\${config.RestAPI}/
    addfile', {
    method: POST
    body: file
    });

    if (response.status === Success) then {
            json = response.json();
            return json;

    else if(response.status === failed)
    then {
            return WebServiceError
            .FileAlreadyExists;
    }
    else {
            return WebServiceError
            .DifferentAddError;
    }
}
end
```

store addFile(file) This function is used to store assets into an EESP distributed network, the process starts from sending an asset storage request by using the Rest API POST method. **Response.status** is used to notify the owner of the status of the asset that you want to keep, if the process fails because the asset is duplicated it will display an error message.

Algorithm 4. EESP Get File

```
get getFile(eespHash) {
        response = fetch('${config
        .RestAPI}/
        getfile?hash=${eespHash}', {
        method: 'GET'
        });

        if (response.status === Success)
        then {
            fileInfo = response.json();
            return eespFile(fileInfo.hash,
            Date(fileInfo.unixTimeAdded
            * 1000)
            .toString(), fileInfo.exists,
            fileInfo.url);
        }
        else if(response.status === failed)
        then {
            return WebServiceError
            .FileNotExist;
        }
        else {
            console.log('hash: '+ hash +'
            status: '
            + response.status);
            then
            return WebServiceError
            .DifferentGetError;
        }
    }

end
```

get getFile() This function is useful for accessing assets stored in the EESP network, by making use of the Rest API GET method based on the received eespHash.

Response.status function is used to notify asset owners about the current status of wanting to access their stored assets. If the status is successful then information about the asset will be

No	Timestamp	Transaction Hash	Transaction Fee (Ether)	Gas Price (Ether)	Gas Price (Gwei)	Gas Used by Transaction	USD
1	Oct-25-2021 08:14:11 AM +UTC	0x5d7d45d2267a4286424682270d737e4 1666a7d969c8983836f19dfefbeee2937	0.0002251500027	0.00000000250000003	2.50000003	90,060 (100%)	0.95
2	Oct-25-2021 08:14:52 AM +UTC	0x292f56e187e007ccc7c7e7974bcf4ad5 3f7684a5a8c6413c8fc3758fc1e3f274	0.0002251500019	0.000000002500000021	2.500000021	90,060 (100%)	0.95
3	Oct-25-2021 08:15:17 AM +UTC	0x585469694c4d58f9a1a7756a90cc90c2 e3740cfe929d67fc1ae80048ebbedc22	0.0002251500014	0.000000002500000016	2.500000016	90,060 (100%)	0.95
4	Oct-25-2021 08:15:42 AM +UTC	0x3ebfca0a663fe7744ea6aa0599e5bdfa1 24966ac2e656e82bc60ec59322a4fff	0.0002251500014	0.000000002500000015	2.500000015	90,060 (100%)	0.95
5	Oct-25-2021 08:16:41 AM +UTC	0x852f221db85486ad7a7cbf8907df1618 4c64ac338d88c565e54ea46a336589b8	0.0002251500009	0.00000000250000001	2.50000001	90,060 (100%)	0.95
6	Oct-25-2021 08:17:12 AM +UTC	0xb726dacce73aa427e8f2332969778de4 d9686a852469cedf0b7941e84339f17b	0.0000759000003	0.00000000250000001	2.50000001	30,360 (100%)	0.32
7	Oct-25-2021 08:18:00 AM +UTC	0x759ab5852ac151062405c844588de5a 77cf3c4744315dd5764fe8735cd4d5c4d	0.0002251500008	0.000000002500000009	2.500000009	90,060 (100%)	0.95
8	Oct-25-2021 08:18:00 AM +UTC	0xf6e3833fe8e034f9108c1c60b5498443 730d68d79f5aa5c334ea96f97c97adb6	0.0002251500008	0.000000002500000009	2.500000009	90,060 (100%)	0.95
9	Oct-25-2021 08:18:00 AM +UTC	0x39d0599c096496354baad69a9558963 209b32f91bb07581e6262ad6357e04600	0.0002251500008	0.000000002500000009	2.500000009	90,060 (100%)	0.95
10	Oct-25-2021 08:18:51 AM +UTC	0x46e2b750f366b038584bfbda443d1f03 ee1f1c01f1de8957568adec513dfa2d6	0.0002251500009	0.00000000250000001	2.50000001	90,060 (100%)	0.95

FIGURE 10 | EESP Performance proof.

displayed, while the failed status will display an error message such as the asset is not available until another error message.

4 EESP ANALYSIS

This paper, in particular, highlights the novelty in synthesizing blockchain technology, a content-addressable storage mechanism, and blockchain smart-contract technology to create an EESP decentralized storage system for higher education. We gain significant benefits compared to the traditional centralized storage systems for data storage and accessibility in the education domain. In this chapter, we will discuss the experiments and the results. Then, this chapter concludes on the EESP framework's contributions in terms of security and privacy.

To run the experiments, we use GitHub and set up the truffle simulators, which consist of four main engines: Solidity Framework, Ganache, Dapp's frontend libraries, and truffle simulator. The comprehensive solidity code is in this paper **Supplementary Appendix SA**. To facilitate researchers to conduct further investigations and replicate the work, we include the GitHub release.

We ran 750 simulations for 25 days, and we found astounding discoveries that this framework applies to decentralized education space. Further rigorous experiments integrating other aspects of education functions still need to be conducted to prove our claims, which is beyond the scope of this paper. Indeed, this work contributes to laying the foundation for further leaps and bounces of advancement in decentralized education space. **Supplementary Appendix SB** provides a few samples of results, including gas usage and gwei consumptions. In **Figure 10** we further assimilate those results into tables to provide a more vivid visual representation.

Based on the experiments and results, we would like to paint the landscape of our discoveries comparing traditional education with the newly proposed decentralized education. It is essential to understand that our focus is on the storage domain. We have highlighted this argument in **Section 1** of this paper that finding the perfect storage solution is crucial and pivotal for further development and advancement of the technology.

Avoid Single Point of Failure:

Unlike traditional centralized storage, our EESP decentralized storage system adopted for higher education can solve the problem of a single point of failure in our solution. With P2P, data owners have the ability to distribute and share files securely because micro-teaching data is hashed. When users need micro-teaching data, P2P networks will quickly provide it. Furthermore, the EESP framework has incentives for users who can provide nodes for those who need it. If users do not want to enable their nodes, they can still store and share files on the EESP network.

Avoid High Redundancy

Micro-teaching data reliability and availability are ensured by runs on a peer-to-peer basis, uses DHT routing technology, with higher data throughput, and low redundancy.

Avoid Third Parties

In centralized storage schemes, we need to rely on service providers to perform search operations honestly and provide appropriate results. However, the service provider may return incorrect results or return no results to save resources, etc., so that the user pays for the service but cannot enjoy the service. In our solution, the EESP framework ensures fairness of the search process through content-addressable storage and smart contracts. The process of storing content-addressable is that when requesting a specific resource that has been hashed, it doesn't need to specify a location, it just needs to specify what to look for. Smart contracts can perform search operations honestly and according to predetermined logic, and the reliability and availability of data can be guaranteed. So that data owners can control their own data.

The contributions of the research are as follows, we were able to create the EESP framework and combine a decentralized storage network for micro-teaching with blockchain and smart contract as a control layer. Users in the civitas community can act as a storage provider or consumer or both. Blockchain smart contract governs between users, rewarding providers and charging consumers. The EESP framework is sustainable because users are incentivized to contribute. It can be stated that as long as the blockchain network and the EESP framework are secure, so is the proposed framework.

5 CONCLUSION AND FUTURE WORK

This research suggests that we should migrate from classical centralized storage into innovative decentralized schemes in the education sector. To achieve this purpose, we introduce a novel EESP framework coupled with a blockchain smart contract that contributes to making significant changes and improvements compared to the current system. The findings of the EESP framework can be applied for the benefits of humanity in this digital era, users in education can store all micro-teaching data securely, will no longer suffer from a single point of failure, high redundancy issues, and no more third party can intervene with and benefit from the network of our framework. We synthesize a blockchain smart contract, assimilating it into the EESP framework so that each hash information micro-teaching can be saved to the node's blockchain. Our future work is to assemble more educational functions and applications into the EESP framework and then do more rigorous simulations and more in-depth customization optimization for content-related services in micro-teaching education.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

UR, MN, RB, QA, MH, and FO contributed to the activities. QA, MH, and FO manage the database of activities. UR, MN, and RB wrote the first draft of the manuscript. All authors contributed to manuscript revision, reading, and approval of submitted versions.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2021.782969/full#supplementary-material

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